EFFECT OF VOWEL CONTEXT AND PHONEME POSITION ON CORRECT ARTICULATION OF PHONEMES IN MALAYALAM SPEAKING CHILDREN WITH DOWN SYNDROME: A PRE POST THERAPY COMPARISON

A DOCTORAL THESIS

Submitted to the University of Mysore for the Degree of

Doctor of Philosophy in Speech-Language Pathology

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DECLARATION

This is to declare that the thesis entitled "**Effect of vowel context and phoneme position on correct articulation of phonemes in Malayalam speaking children with Down syndrome: A pre post therapy comparison**" which is submitted herewith for the award of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore, Mysuru, is the result of my own study under the guidance of Dr. N. Sreedevi, Professor of Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru. I further declare that this has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that the thesis entitled "**Effect of vowel context and phoneme position on correct articulation of phonemes in Malayalam speaking children with Down syndrome: A pre post therapy comparison**" submitted by Ms. Anitha Naittee Abraham, for the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore, Mysuru, has been prepared by her under my guidance at the All India Institute of Speech and Hearing, Mysuru. It is also certified that this has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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Abstract

Evidence on contextual coarticulatory facilitation of speech sound production is valuable for speech correction and is documented as single case studies on a number of phonemes in the past, majorly in English, and scanty in Indian languages. As the facilitating influence of vowels on consonant production varies across languages, such contexts need to be established and validated in different languages and clinical populations with speech sound errors.

In spite of having good language abilities, reduced speech intelligibility interferes with the communication efficiency of individuals with Down syndrome (DS). Speech intelligibility of children with DS improves with intervention even though the learning pace is slow. Hence it is necessary to establish facilitating vowel contexts and phoneme positions to ensure faster improvement in this population.

The present investigation was designed as a single subject study to establish facilitating vowel contexts and phoneme positions in the correct production of phonemes by children with DS in Malayalam. Fifteen Malayalam speaking children with DS in the age range of 7-13 years served as participants of the study. Ten frequently misarticulated phonemes in Malayalam were selected for articulatory intervention which included unvoiced retroflex stop /ʈ/ (4 participants), voiced retroflex stop /ɖ/ (4 participants), retroflex nasal /ɳ/ (5 participants), retroflex lateral /ɭ/ (5 participants), unvoiced velar stop /k/ (1 participant), alveolar fricative /s/ (3 participants), retroflex fricative /ʂ/ (3 participants), alveolar tap /r/ (2 participants), alveolar trill /ṛ/ (1 participant) and retroflex approximant /ɻ/ (2 participants).

Two wordlists with the target phonemes occurring in the context of various vowels in initial and medial positions were prepared for assessment and intervention. Assessment wordlist was used for obtaining baselines and intervention wordlist was used as stimuli for therapy. Verbal imitation task was employed for elicitation of responses. For each phoneme, participants received a maximum of 10 sessions of therapy, determined based on a pilot study. Participants received a total of 340 articulation therapy sessions using phonetic placement approach (Van Riper, 1972). Percentage of correct production was computed for each context across sessions and the data was represented graphically. A pre-post therapy comparison was done using Wilcoxon signed rank test. However, no significant difference was seen in spite of higher post therapy scores in multiple contexts. As applying statistical analysis could not explain the findings of the present study appropriately, the data was analysed qualitatively using graphical representations. Three measures, Minimum Number of Sessions for Correct Production (MNS-CP), Minimum Number of Sessions for Consistent Correct Production (MNS-CCP) and Total Number of Sessions with Correct Production (TNS-CP) were computed from the graphs to address the objectives of the study.

Findings revealed a definite effect of vowel context and phoneme position on correct production of phonemes in children with DS. Facilitating vowel contexts identified were high back vowel /u/ for /ʈ/, /ɳ/, /ɭ/ and /ʐ/, mid back vowel /o/ for /ɖ/, /ṛ/ and /ʂ/, high front vowel /i/ for /s/ and /r/. Consonant /k/ was favoured by multiple vowel contexts; /a/, /u/ and /o/. Initial position facilitated the production of four phonemes (/ɖ, s, ʂ, k/) and medial position favoured three phonemes (/ʈ, r, ṛ/). The findings of the present study can be adapted for assessment and intervention of speech sound errors in children with DS in Malayalam. For practicing speech language pathologists, these established facilitating contexts will serve as a quick reference guide to save significant time and effort involved in the speech correction process.

***Keywords*:** Down syndrome, vowel context, phoneme position, contextual facilitation, Malayalam

Chapter 1: Introduction

Intelligible speech plays a critical role in human society and is the most crucial indicator of oral communication competence. The development of speech is a complex process that requires coordination between the brain and the articulators where the muscles move in precise timing to articulate and produce meaningful combinations of speech sounds. The brain coordinates these individual articulator movements in a very ingenious way, such that movements needed for adjacent vowels and consonants are produced simultaneously. This results in coarticulation, where the articulation of one phoneme is influenced by preceding and following phonemes. The interaction between phonemes due to coarticulation can either facilitate or interfere with the correct production of a phoneme. Facilitation is defined as a relative improvement in judged adequacy of sound production determined by phonetic factors such as stress, contexts, and neighbouring words (Kent, 1982). Specific phonetic environments or linguistic conditions are more likely than others to be associated with the correct production of a phoneme (Curtis & Hardy, 1959; Gallagher & Shriner, 1975). Similarly, phonemes are produced more accurately in certain word positions than others, which are evident from developmental and clinical studies.

Developmental evidence suggests there is a preferential occurrence of phonemes with certain vowels. According to the Frame-Content hypothesis (Davis & MacNeilage, 1995), there are key environments for producing speech sounds. It was observed that there is co-occurrence of consonants with certain vowels: front consonants like alveolars with front vowels, velars with back vowels, and bilabials with central vowels in babbling samples (Davis & MacNeilage, 1995). Frame-content hypothesis was also tested in Indian languages, including Malayalam (Alphonsa & Sreedevi, 2012; Irfana & Sreedevi, 2012) and Kannada (Shishira & Sreedevi, 2016;

Sushma & Sreedevi, 2016) and preferential occurrence of consonants with vowels was documented.

Literature on behavioural studies regarding contextual influences has shown a definite effect of vowel contexts on the production of speech sounds in both typically developing children and children with speech sound disorders. Several physiological, acoustical, and perceptual evidence supporting the behavioural studies on vowel contexts and phoneme position influences on the production of sound sequences. The systematic physiological investigations on tongue muscles signify the contextual effects on EMG activity for consonants and vowels in CVC syllables (MacNeilage & DeClerk, 1969). X-ray studies also provide physiological evidence on the influence of vowels on the tongue positions of consonants (Borden & Gay, 1979; Carney & Moll, 1971; Kent & Moll, 1969; Subtelny et al., 1972). Menon et al. (1969) found vowels influencing the spectra of fricatives through acoustical evidence.

Facilitative vowel contexts were used in speech therapy as well. The use of conducive vowel contexts draws on the traditions of articulation therapy (for example, Van Riper, 1972), and some of the principles of integral stimulation therapy (for example, Strand & Skinner, 1999), and phonotactic therapy (Velleman, 1998, 2002). The place and manner features of neighbouring vowels can be used to achieve correct placement of the following consonant segment, hence spreading the place properties of one segment to another. Irwin and Weston (1971) reported data for 388 children treated with paired-stimuli approach achieving 80% correct response in a non-contingent single-word probe condition. Bleile (2015) prefers key environment utilization for articulation therapy in children with speech sound disorders, typically under 4- to 5-years of age. Researchers reported that phonetic contexts in intervention has shown speedy recovery in children with speech sound disorder (Stringfellow & McLeod,1994; Stokes & Griffith, 2010). Case studies reported facilitatory effects of vowels in the production of consonants in English (Lancaster & Pope, 1989; Cleland et al., 2015). Studies on similar lines were reported in Indian languages; Kannada (Krishna & Manjula, 1991; Amulya, 2018) and Malayalam (Anu Rose & Sreedevi, 2017). In an extensive study in Kannada, facilitatory effect of vowels on correct production of nine phonemes were documented (Amulya, 2018). However, in Malayalam, there are no such extensive studies published on facilitating contexts.

The effect of phoneme position on the production of phonemes was also documented in English. Phonemes acquired in certain word positions are easier compared to others. Fleming (1971) stated, "An individual will usually be able to produce his problem sound most easily in initial or final positions whether the context is a syllable, word, phrase or sentence". However, this finding is not universal and is language-specific. Most of the phonemes are acquired earlier in the initial position compared to the final position in English (Bleile, 2006; Dodd et al., 2003; Smith et al., 1990; Stoel-Gammon, 1981; Watson & Skucanec, 1997) and French (McLeod et al., 2011) whereas, in Arabic, it was in medial position followed by initial and final positions (Amayreh & Dyson 1998). In the Indian context, studies on articulatory acquisition are explored in various languages like Kannada (Deepa & Savithri, 2011), Malayalam (Neenu et al., 2011), Telugu (Usha Rani & Sreedevi, 2011), Odiya (Pooja & Sreedevi, 2016) and documented early acquisition of phonemes in certain positions.

Clinical observations and various studies suggest that the production of phonemes is facilitated more easily in certain phoneme positions (Curtis & Hardy, 1959; Houde, 1967; Bauman- Waengler, 2012; Shalini & Sreedevi, 2016; Merin &

Sreedevi, 2017; Amulya, 2018; Bleile, 2006). Therefore, exploring such facilitating environments becomes necessary to improve the speech characteristics of individuals with speech disorders.

Facilitating phonetic contexts in correction of speech begins with selecting appropriate stimuli for intervention. In the early stages of articulation training, the clinician needs to begin with syllables, words, phrases, and sentences that are easily discriminated and produced by the clients. Such a hierarchy of facilitating contexts augment the pace of learning of children with speech sound errors. Such facilitative contexts should be established in different languages and must be validated in various clinical populations with speech sound errors to speed up speech intelligibility.

Among various communication disorders which co-occur with speech sound disorder, intellectual disorder (25.44%) occurs most frequently, followed by hearing loss (14.65%), brain injury (10.28%), autism spectrum disorder (4.88%), and oral mechanism abnormality (3.59%) (Kim et al., 2015). Intellectual disability is a mental disorder characterized by significant limitations both in intellectual functioning and in adaptive behaviour as expressed in conceptual, social, and practical adaptive skills (DSM V, American Psychological Association, 2013). It is present in 2 to 3% of the population either as an isolated finding or as part of a syndrome or a broader disorder (Daily et al., 2000). According to the Government of India census (2011), intellectual disability accounts for 5.6% of the total population of disability. Down syndrome is the commonest identifiable cause of intellectual disability, accounting for around 15-20% of the intellectually disabled population. DS is estimated to occur once in every 700–800 live births, with a global incidence of more than 200,000 cases per year (Contestabile et al., 2010).

Down syndrome is a chromosomal disorder that results from an extra (third) copy of chromosome 21 (trisomy 21). It is characterized by mild to moderate intellectual disability, hypotonia, distinctive facial features such as microgenia (an abnormally small chin), round face, macroglossia (protruding and oversized tongue), epicanthal fold (a fold of skin on the eyelid), short stature and shorter limbs, hyper-flexibility of joints (Chapman et al., 1998). The cognitive phenotype of DS is characterized by a disproportionate deficiency in language development as opposed to social intelligence. The classic language profile of children with DS is that language comprehension skills are on par with mental age controls, but the production skills in terms of speech intelligibility lag far behind (Lenneberg, 1967)

Several investigations on speech and language of individuals with intellectual disability have reported that articulatory/phonological problems are particularly severe for children with Down syndrome (Blanchard, 1964; Dodd, 1976; Dodd et al., 1989; Rosenberg & Abbeduto, 1993; Stoel-Gammon, 1981). There are many reasons for this, including anatomical, cognitive and physiological factors. The physical characteristics combined with low muscle tone contribute to the difficulty children with DS have in producing the precise sounds and sound combinations required for intelligible speech (Kumin, 1996; Spender et al., 1995; Spender et al., 1996). Such phonological/articulatory errors negatively impact speech intelligibility, which is further documented as a primary concern of parents and caregivers of individuals with DS (Kumin, 1994; Pueschel & Hoppmann, 1993). This emphasizes the need to target the speech intelligibility of children with DS during speech and language intervention. However, speech-language pathologists and educators working with children and adults with Down syndrome have focused less on problems with speech and its intelligibility during intervention programs (Kumin, 1986).

Most of the intervention programs for remediating the speech sound errors in individuals with DS have focused on increasing the phonetic repertoire and reducing the number of speech sound errors in single word productions, using therapy techniques similar to those for children with phonological delays or disorders. Literature on speech-language intervention of DS is very limited, and two treatment studies reported a phonological approach positively influenced speech intelligibility in them (Cholmain, 1994; Dodd et al., 1994). In a recent study, Broad Target Speech Recasts (BTSR) therapy was found to improve speech comprehensibility in children with DS (Yoder et al., 2016). However, the learning pace of these individuals was reported to be slow. Improving speech intelligibility will enhance the social and vocational placement of individuals with intellectual disabilities. Hence, Shriberg and Widder (1990) argued that correction of the articulatory errors should be a mandatory goal during the intervention of children with DS, though the progress is slow and the resources are limited. This stresses the need to target speech sound correction using facilitating phonetic contexts to ensure faster improvement in individuals with DS.

1.1.Need for the study

Literature review on SSD intervention reports several studies on the importance of facilitation contexts for speech correction. On analysing the past evidence on contextual influence on phonemes, most of the studies were clinical observations conducted in the Western context during 1940 – 1960. Significant limitations of these studies were limited sample size, confining to one or two phonemes, and was not intervention based. Few studies with single-subject designs had a limited number of target phonemes, but they focused on studying contextual influence during the generalization phase on untrained stimuli (Elbert & McReynolds, 1975, 1978). The studies applying the knowledge of key environments (Stringfellow & McLeod, 1994; Stokes & Griffith, 2010) are also confined to only one phoneme. The key environments for various speech sounds established by Bleile (1991, 1996, 2006) and Bauman-Waengler (2012) are solely based on clinical observations, and they have advised for validation of results by replicating such studies. Generally, these Western studies are confined to late acquiring sounds, especially /s/ (French et al., 1930) and /r/ (Carterette & Jones, 1974), as both are the most frequently occurring and erred sounds in English, leading to speech unintelligibility.

Although various studies report on the facilitating influence of vowels on consonant perception and production, the extent of vowel influence varies across languages (Boyce, 1990; Magen, 1984; Manuel, 1990; Manuel & Krakow, 1984). A recent physiological study by Irfana (2017) on coarticulation in Indian languages using ultrasound imaging supports this finding stating that Dravidian languages like Malayalam and Kannada exhibited higher coarticulation resistance of consonants and vowels than Indo-Aryan languages like Hindi. In addition, the co-articulation properties differ across sound classes (Ohman, 1966). Variations in vowel influences can probably be because co-articulation is language-specific (Bladon & Al- Bamerni, 1976; Geng, 2008; Lindblom et al., 2007; Mc Allister& Engstrand, 1992; Perkell, 1986; Sussman et al., 1993) to a large extent and findings in English, and other languages cannot be fully extended to Indian languages as there are subtle changes in the physiological aspects of speech sound production across languages. For example, extensive X-ray and ultrasound studies show retroflection varying with degree of curvature of the tongue and the exact location of constriction (Ladefoged & Maddieson, 1996; Svarny & Zvelebil, 1955; Ladefoged & Bhaskararao, 1983). In an ultrasound imaging study, Sindhusha et al. (2014) found unvoiced Kannada retroflex to depict apical and voiced as sub-apical patterns. In contrast, both voiced and unvoiced retroflexes in Malayalam have a sub-apical pattern.

Clinical data reveals that velars, retroflex, trill, flaps, fricatives, and affricates are frequently erred sounds in Malayalam. These are seldom addressed in phonetic context (vowel and phoneme position combination) studies. There are only a few Indian studies targeting children with communication disorders on these lines. Krishna and Manjula (1991) established the effect of vowels on the correct production of Kannada unvoiced retroflex /ʈ/ on a single participant. Anu Rose and Sreedevi (2017) studied vowel influences on velar production, and Merin and Sreedevi (2017) examined phoneme position effects on affricate and fricative production in six Malayalam speaking children with hearing impairment. Amulya (2018), in a doctoral study on Kannada speaking children with speech sound disorders, targeted nine frequently errored phonemes. The majority of Indian studies have focused on limited number of speech sounds and lesser number of participants. The influence of vowel contexts and phoneme positions on other cognates of retroflex (voiced, nasal and lateral), velars, affricates, and fricatives in Malayalam are not established. Studies on typical articulation development focus on phoneme production and not on contextual facilitation. Hence it is important to conduct much structured studies on most commonly misarticulated phonemes in multiple languages and also in various clinical population with speech sound errors.

From the past literature it is evident that due to many anatomical, physiological and cognitive factors, speech intelligibility is affected in individuals with DS. Communication breakdown resulting from reduced speech intelligibility is a major concern in these individuals. A deficit in verbal communication may lead to diminished social skills, behavioural problems and isolation, as it allows the exchange of needs and feelings, facilitates thinking and contributes to developmental and learning processes (Lawrenson et al., 1997). In the domain of speech and language, efforts are often directed towards increasing the functional communication skills necessary for social interaction and vocational training with little emphasis on phonological skills per se. By investing in improving the quality of their speech, one can improve communication and, by extension, their quality of life in general.

In India, articulation therapy for children with Down syndrome is seldom conducted using the facilitating contextual and positional effect as such information has not been documented. To bridge these gaps in research and from a clinical point of view, it is viable and advisable to seek for phonetic contexts in different languages for all the phonemes which consistently facilitate quick production of the target phonemes in an individual. "Such correct production may be 'nuggets of gold' to be used in speeding the establishment of correct habit patterns" (McDonald, 1964) in therapy. Hence a systematic study in this direction will give more insight regarding the underlying patterns involved. Thus, a hierarchy of facilitating contexts and positions can be obtained so as the intervention goals can be planned according to this. It will be helpful in reducing the time and effort involved in the speech remediation process. With this insight the present study aims at establishing specific vowel contexts and phoneme positions to facilitate the correct production of target phonemes in Malayalam speaking children with Down syndrome. Utilising such facilitating contexts would certainly reduce the duration of intervention and ensure faster improvement in speech intelligibility. For busy practicing speech language pathologists, these evidence based facilitating contexts will help to save significant time and effort involved in the speech correction process.

1.2. The Current Study

On identifying the research gaps in the area of contextual facilitation of speech, the current study was designed to investigate the facilitating vowel contexts and phoneme positions in children with Down syndrome in Malayalam. Studies on contextual facilitation in the past were mostly single case studies. No controlled study on establishing facilitatory phonetic contexts were conducted. Researchers opined that facilitating contexts generally vary across clinical population and it is essential to conduct detailed analysis regarding the same (Curtis & Hardy, 1959). Also, the results obtained from group design studies on facilitating contexts are difficult to generalize to an individual (Zehel et al., 1972). In this context, the current study was designed as a single subject study (AB design) to address the homogeneity and heterogeneity in facilitating contexts in the target population. In the AB design, a baseline of the target behaviour is first established; the treatment is then applied and the dependent variable is measured continuously. When the treatment objective is achieved, a report is made on the recorded changes in the client behaviours. As AB design lacks experimental control of extraneous variables, it is a case study design. Case studies are valuable tools of clinical research and their positive results may prompt for more controlled research. Negative results of an AB study, on the other hand, are a significant finding because a treatment that does not produce an effect under uncontrolled conditions is unlikely to produce an effect under controlled conditions. Carefully designed studies with multiple observations before, during, and after treatment with stable measures and good contrast can enhance the validity of AB studies (Hegde & Salvatore, 2019).

Creswell (2013) defines case study method as "explores a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information and reports a case description and case themes". Despite the on-going debate about case studies' credibility and limitations, especially concerning generalization, replication, and researcher bias, it is still increasingly accepted among researchers (Hyett et al., 2014; Thomas, 2011). The reasons for choosing a case study method in the present study are as follows:

a) It is a flexible method (Merriam, 2009; Stake, 1995)

b) Examines individual-level data by allowing highly accurate estimates of within-subject variability and longitudinal trajectories of each behavior (Velicer & Molenaar, 2013) with better precision due to a higher number of data points and better-controlled variability of the data (Kazdin, 2011).

c) Allows for a highly accurate assessment of the impact on intervention for each participant while group level designs provide information on the effectiveness of the intervention on an average rather than any person in particular (Velicer & Molenaar, 2013).

d) Explores and describes the nature of processes which occur over a period in contrast to experimental studies providing stilled snaps (Hayes, 2000).

e) Leads to various insights for further research (McLeod, 2008)

Gibbert and Ruigrok (2010) have put forward four criteria to bring rigidity in case study methods. In the present study, an effort is made to meet all the four criteria and details are provided in Appendix I.

1.3. Aim of the study

To study the effect of vowel contexts and phoneme positions in facilitating the correct production of frequently misarticulated phonemes by native Malayalam speaking children with Down syndrome.

1.4. Objectives

The specific objectives of the study are as follows:

1. To study the effect of vowel contexts (/a/, /i/, /u/, /e/ and /o/) on the correct production of ten frequently misarticulated phonemes in Malayalam speaking children with Down syndrome.

2. To obtain the rank order of vowel contexts facilitating the production of ten frequently misarticulated phonemes in Malayalam speaking children with Down syndrome.

3. To study the effect of phoneme position (initial or medial) on the correct production of seven frequently misarticulated phonemes in Malayalam speaking children with Down syndrome.

4. To obtain the rank order of phoneme positions facilitating the production of seven frequently misarticulated phonemes in Malayalam speaking children with Down syndrome.

5. To study the interaction effect of vowel contexts and phoneme position on production of seven frequently misarticulated phonemes in Malayalam speaking children with Down syndrome.

Among the 10 phonemes considered in the present study, only seven phonemes occur in both initial and medial positions in Malayalam. Hence in the third and fourth objectives to check the effect of phoneme position (initial and medial), only these seven phonemes are considered. The present study concerns establishing the facilitating vowel contexts and phoneme position in children with DS and not the efficacy of any articulation therapy approach.

1.5.Hypotheses

The present study follows a single subject design. Unlike group design strategy, testing of hypothesis is generally not done in single subject designs as inferential statistical tests cannot be applied in such designs (Hegde & Salvatore, 2019). However, in the present study an attempt was made to run non parametric statistical tests for pre-post therapy comparison of phonemes which was intervened in a minimum of three participants. Among the 10 phonemes considered for intervention, six phonemes (/ʈ, ɖ, ɳ, ɭ, s, ʂ/) were intervened in more than three participants. Effect of vowel context was studied in six phonemes and effect of phoneme position in four phonemes as the phonemes /ɳ/ and /ɭ/ does not occur in initial position in Malayalam. Hence hypotheses were formulated as stated below.

1. There is no effect of vowel contexts (/a/, /i/, /u/, /e/ and /o/ respectively) on the correct production of six frequently misarticulated phonemes (/ʈ, ɖ, ɳ, ɭ, s, ʂ/) in Malayalam speaking children with Down syndrome.

2. There is no order of vowel contexts in facilitating the correct production of six frequently misarticulated phonemes (/ʈ, ɖ, ɳ, ɭ, s, ʂ/) in Malayalam speaking children with Down syndrome.

3. There is no effect of phoneme position (initial or medial) on the correct production of four frequently misarticulated phonemes (/ʈ, ɖ, s, ʂ/) in Malayalam speaking children with Down syndrome**.**

4. There is no order of phoneme position in facilitating the correct production of four frequently misarticulated phonemes (/ʈ, ɖ, s, ʂ/) in Malayalam speaking children with Down syndrome.

Chapter 2: Review of literature

Speech is considered as the most effective verbal way of expressing thoughts, needs, events, and so on, for children and adults and it tends to be the most cognitively and physiologically demanding communicative means. Speech development is a complex process that demands learning and use of different interlinked cognitive and articulatory strategies, such as coordination between brain systems and the speech articulators and using and moving the right muscles in precise timing to articulate and produce meaningful combinations of speech sounds (Buckley & Le Prevost, 2002). The brain coordinates these individual articulator movements in a very ingenious way, such that movements needed for adjacent vowels and consonants are produced simultaneously. This results in speech being produced very smoothly. At the same time, it spreads out acoustic information about a vowel or consonant and helps a listener understand what is being said. This interaction between phonemes is termed as coarticulation.

2.1. Coarticulation

Coarticulation refers to the articulatory modification of a speech sound under the influence of adjacent segments (Daniloff & Hammarberg, 1973; Kent & Minifie, 1977). In other words, the articulation movements of a sound are influenced by sounds that closely precede and follow it. It can be defined in physiological, acoustic and perceptual dimensions. Physiological measurements of coarticulatory effects demonstrate that features specific to certain sounds spread to adjacent segments across phrase, word, and syllable boundaries (Daniloff & Moll, 1968; Amerman et al., 1970; Moll & Daniloff, 1971; Carney & Moll, 1971; Kent & Minifie, 1977). This takes place due to the integration of neural commands to the speech musculature, timing and movement patterns of articulators and aerodynamic forces. Acoustically, it refers to the influence due to modifications by certain contextual cues for consonants and vowels, in the perception of sounds. Perceptually, it refers to the listening effects of the contextual cues for consonants and vowels, in the perception of sounds.

Due to coarticulation, the place of consonant articulation varies according to the properties of other segments, both within and across words (Hoffman & Norris, 1989). This effect can either facilitate or inhibit correct articulation of a phoneme. That is, certain phonetic environments or linguistic conditions are more likely than others to be associated with the correct production of a phoneme. Gallagher and Shriner (1975) observed that the place of articulation of neighbouring sounds is more responsible for the accurate production of phonemes than probably manner of articulation. The coarticulatory context conditions which aids the correct production of a target sound is called as facilitating contexts.

Many theories have been proposed to explain the facilitatory effect of phonetic contexts. The facilitating effects of certain phonetic contexts on correct sound production seem to occur because the overlapping or interaction of articulations between two or more sounds enhances the production of a sound that may be misarticulated in other environments. This physiologic facilitation could be reasoned in two ways. First, the context may be facilitating because it minimally interferes or competes with the error sound. A client will more likely produce the misarticulated sound correctly in a context if the articulatory movements of tongue, lip, palate and jaw required to articulate the context are minimal. If the articulatory movements required for the neighbouring sounds interferes with the correct placement of articulators for misarticulated sound, it results in increased probability of erroneous productions. For example, in a study by Swisher (1973), initial /sp-/ cluster was associated with a high rate of correct /s/ production in children who had inconsistent errors for this sound. Apart from both being oral sounds with velopharyngeal closure and voicelessness, /s/ and /p/ do not have contradicting articulatory gestures. Perhaps bilabial /p/ facilitates correct production of the lingua-alveolar /s/ because /p/ simplifies or reduces the articulatory demand on the tongue in the neighbourhood of the /s/ sound. A second facilitation arises because of similarity between the error sound and its phonetic neighbour(s). For example, the word-initial cluster /st-/ was highly facilitating to produce /s/. These two sounds are highly similar and this similarity in articulatory features may promote the correct articulation of /s/ (Swisher, 1973).

Facilitation is determined by phonetic factors such as stress, position, context, juncture, adjacent consonants, rules of the language and neighbouring words (Kent, 1982). Evidences on contextual facilitation dates back to 1940s, where researchers found a systematic association between the specific phonetic contexts and greater frequency of correct productions of these sounds (Nelson, 1977). Studies confining to effect of vowels, consonants in blends, phoneme positions, and juncture in English are ample in number. The following sections pertain to the influence of vowels and phoneme positions on production of speech sounds during acquisition of speech sounds and in clinical population.

2.1.1. Effect of vowel context on speech sound acquisition

The place and manner features of neighbouring vowels can be used to achieve correct placement of the following consonant segment by spreading the place properties of one segment to another. The facilitative effects of consonant vowel pairing are believed to be due to the maintenance of an articulatory gesture from one segment to the next, as neuromuscular demands are organized for initiation prior to the segment for which they are required (Clark et al., 2007).

Context-based interaction of sounds and their effect on ease of production of phonemes had been studied in typically developing children. According to Frame-Content theory (Davis & MacNeilage, 1990) there are key environments to produce speech sounds. Babbling in infants occurs as syllables (syllable structures are referred to as frames) with consonants and vowels arranged within these frames (content). It was observed that there is co-occurrence of consonants with certain vowels: front consonants like alveolars with front vowels, velars with back vowels and bilabials with central vowels. Vihman (1992) studied the first 50 words of 23 children across four languages namely, American English, French, Japanese, and Swedish and the results showed co-occurrences of the sequence of bilabial consonants with central vowels and velar consonants with back vowels were strongly supported in all four languages. Although the alveolar consonants and front vowels association was observed, the association was not as strong as that between the former two.

Boysson-Bardies (1993) studied groups of five 10-12- month-old infants from four different language communities (French, English, Swedish, & Yoruba). It was found that CV patterns in the infants were influenced by characteristics of the target language. Labial-central vowel association in initial syllables was found for French, Swedish, and Yoruba infants. American infants showed an association between labials and front vowels. A favoured association between dentals and front vowels was found in English, Swedish, and French; between dentals and central vowels in Yoruba. Oller and Steffans (1993) noted some association consonants and vowels within syllables in a study on infants. Coronal consonants were more frequently associated with front vowels, dorsals more frequently with back vowels. Coronals showed the greatest association with high vowels, labials the greatest association with low vowels.

The presence of phonological patterns for initial consonants in the context of front, central, and back vowels was investigated by To et al. (2013) in children aged between 2.6-to-6.0 years in Cantonese language. Significant reduction in fronting of /k/ to /t/ and /k^h/ to /t^h/ in back vowel context and stopping of /s/ to /t/ and /ʧ/ to /t/ in front vowel context was observed. However, a significant increase in affrication of /t/ to /ʧ/, /s/ to /ʧ/ and deaffrication of /ʧ/ to /s/ and /ʧ^h/ to /s/ was documented in front vowel context.

Facilitatory effects of consonant-vowel pairing was investigated in Indian languages as well. Rohini and Savithri (1989) developed deep test of articulation - sentence form in Kannada and they reported key environments for phonemes in typically developing children. The results of the study are summarised in table 2.1

Table 2.1

Facilitating vowel environments for various phonemes in Kannada (Rohini & Savithri, 1989)

Age	Phoneme	Key environment
5 to 6 years	/d/, /ɳ/, /r/, /v/, /ʂ/	/a/, /i/, /u/, /e/
	/g/, /ɖ/, /c/, /ɟ/	/a/, /i/, /u/, /e/, /o/
	/ɭ/	/i/
	/j/	/a/, /e/
	/s/	/a/, /i/, /u/
	/h/	/a/, /i/, /e/

Age	Phoneme	Key environment
6 to 7 years	/g/, /ɖ/, /c/, /ɟ/, /d/, /r/, /ɳ/, /s/	/a/, /i/, /u/, /e/, /o/
	/ɭ/	/i/
	/v/	/a/, /i/, /e/
	/j/	/a/, /e/
	/ʂ/	/a/, /i/, /u/
	/h/	/a/, /i/, /e/, /o/
7 to 8 years	/g/, /ɖ/, /c/, /ɟ/, /d/, /r/	/a/, /i/, /u/, /e/, /o/
	/v/	/a/, /i/, /e/
	/j/	/a/, /e/
	/ʂ/	/a/, /i/, /u/
	/h/	/e/, /i/, /o/
	/s/	/a/, /i/, /u/, /o/

Similar to Kannada, Maya and Savithri (1990) developed a deep test of articulation - sentence form in Malayalam and documented facilitating vowel contexts in Malayalam in typically developing children. The results are summarized in table 2.2.

Table 2.2

Facilitating vowel environments for various phonemes in Malayalam (Maya & Savithri, 1990)

Age	Phoneme	Key environment
5 to 6 years	/s/, /ʐ/, /j/	/a/, /i/, /u/, /o/
	/ʃ/, /ʂ/, /r/, /R/	/a/, /i/, /u/, /e/, /o/
	/ɭ/	/a/, /i/, /e/, /o/
6 to 7 years	/s/, /ʃ/, /ʂ/, /r/, /R/, /ɭ/	/a/, /i/, /u/, /e/, /o/
	/ʐ/, /j/	/a/, /i/, /u/, /o/
7 to 8 years	/s/, /ʃ/, /ʂ/, /ɭ/, /r/, /R/, /ʐ/	/a/, /i/, /u/, /e/, /o/
	/j/	/a/, /i/, /u/, /o/

Frame content hypothesis was tested in few Indian languages: Kannada and Malayalam. The first attempt was in Kannada by Anjana and Sreedevi (2008) where the participants were 6-to-12 months old infants. Results revealed that high front vowel [i], high back vowels, and central vowels often occurred with dentals, velars, and labials respectively which is in agreement with Frame content hypothesis (Davis & MacNeilage, 1990). It was concluded that infants highly preferred vowel [a] with a majority of consonants during babbling stage since [a] is a frequently occurring vowel in Kannada and is abundantly produced by children of all age groups. Furthermore, place of articulation of vowel [a] places minimal constraints on the tongue movements.

In Malayalam, Irfana and Sreedevi (2012) and Alphonsa and Sreedevi (2012) tested frame-content hypothesis in toddlers (12-24 months) and it was found that the low central vowel /a/ was the most frequently occurring vowel. It occurred most frequently with bilabials followed by dentals and labiodentals, whereas the high front vowel /i/ was most frequently occurring with glide /j/, it also paired with /t, tʃ, h/. The back vowels /u/ and /o/ were sequenced with /p, b, k/. Similar studies were attempted in Kannada and the findings were in partial consonance with the hypothesis. As documented in Malayalam, the bilabials were preferred with central vowel /a/ and coronals and velars appeared most often with high front vowel /i/ in Kannada (Shishira & Sreedevi, 2016; Sushma & Sreedevi, 2016).

Reeny (2017) explored preferential consonant- vowel combination in typically developing children aged 4-to-12 months in Malayalam and Hindi. In Malayalam, the commonly observed CV combinations were velar-front, velar- central, coronal-central, labial-central, labial- frontal, and coronal-frontal. The prominent CV combinations in Hindi were labial-central, coronal-central, velar-central and coronal-frontal.

The above literature sheds light on the significance of co-occurrence of consonants in specific vowel contexts during the speech developmental period as early as the babbling stage suggesting that analyzing such phonetic contexts provides greater understanding for developing an assessment and treatment plan for children with speech sound disorders.

2.1.2. Clinical studies on facilitating effect of vowel contexts

Facilitating vowel contexts have been documented in clinical population as well. Most of the studies were case studies or single subject designs. Earlier English literature on vowel effects is confined to late acquiring speech sounds like fricatives, affricates, and trills.

Production of alveolar fricative /s/ had been extensively investigated in western literature and variable findings were documented across studies. In an earlier study, Muntyan (1963) explored the production of /s/ in 53 kindergarten children aged 5-to 6-years with non-organic speech disorder. Fricative /s/ was investigated in two conditions, prevocalic and postvocalic conditions followed or preceded by selected vowels ([i], [ɛ], [æ], [ɑ], [o], [u], [ɝ], [ʌ]) at mono- or bi-syllabic words and non-words level. The results revealed that post-vocalic [s] was produced correctly most frequently when preceded by back vowel /u/ and least frequently when preceded by front vowel /i/. On the other hand, Zehel et al. (1972) found preceding high vowel /i/ facilitating the production of fricative [s] in few children when /s/ is produced with lips spread and tongue blade in a high front position, articulatory gestures shared with vowel /i/.

An extensive study by Elbert and McReynolds (1978) considered five children with functional articulation errors in the age range 5 years 6 months to 6 years 4 months. Fricative /s/ was taught in limited number of contexts and explored its generalization to other untrained contexts. The target fricative was trained in 6 syllable categories CV, VCV, VC, CCV, VCC, and VCCV with five vowel contexts high front vowel /i/, low front vowel /æ/, /u/, /low backs vowel /a/, and neutral vowel /ʌ/ and two consonant contexts, front consonant /t/ and back consonant /k/. The results indicated that there was a tendency toward the /s/ being produced correctly in the context of high vowels (/i/ and /u/) more often than in the context of low vowels. They concluded that articulatory error forms play a major variable influencing the contexts to which generalization occurs.

In contrast to the findings of Elbert and Mc Reynolds (1978), Bennet and Ingle (1984) reported that prevocalic /s/ was least erred in the context of vowel /ʌ/ and highly erred in the context of word initial cluster in 50 children in the age range of 6-to12- years with functional articulation disorder misarticulating /s/. This study was partially contradictory to the research by Gallaghar and Shriner (1975) describing consonant clusters as the most facilitating context for /s/ than consonant vowel context.

Mazza et al. (1979) investigated the contextual effects on the inconsistency of /s/ production in 10 children with mean age 6 years 8 months misarticulating fricatives /s/ and /z/ interdentally in initial, medial, and final positions of words. The task involved repetition of sound-in-context-sentences and the vowel contexts comprised of /a/, /i/, and /u/. In contrast to the results of other studies, this study results revealed no vowel effect on the production of fricatives and this was attributed to the fact that fricatives are coarticulatory resistant.

Hoffman et al. (1977) studied a group of 10 children with inconsistent production of /r/ using repetition of sentences and found that consonant clusters and preceding vowel contexts served as key environments for the correct production of /r/. The highly facilitating vowel context was long front vowel /æ/, followed by long front vowel /i/, and high back vowel /u/ which was attributed to the fact that the movement necessary for production of /i/ and /u/ are in close proximity with the target [r]. This was attributed to the fact that correct production of vowels /i/ and /u/ requires close palatal and velar approximations in the oral cavity which may be facilitating for the production of /r/ as these positions are in close proximity to the target during right-left coarticulation. Eisenson and Ogilvie (1983) have found that in English speaking children with misarticulation, the phoneme /r/ has to be combined with an unrounded vowel to reduce the lip-rounding of /r/; to facilitate production of /k/, a high-back vowel rather than a high front vowel should be used.

Lancaster and Pope (1989) suggested pairing the post-alveolar fricative with /u/ (back place of production and lip-rounding in manner) to achieve a correct post-alveolar placement and lip-rounding for palatal fricative. In a case study, Stokes and Griffiths (2010) reported that back vowels facilitated the production of palatal fricative, in a seven-year-old monolingual boy with post-alvoelar fronting of fricative. Results also highlighted that selection of vowel context was custom-made to suit the child's needs.

Stringfellow and McLeod (1994) carried out a case study on a 5-year-old English speaking boy with language delay, who substituted /l/ for /j/ and found that vowels /i/ and /a/ facilitated the production of glide /j/. Similarly, back vowels facilitated the production of velar phonemes in English speaking children with speech sound disorder in the age range 5-to 7-years (Cleland et al., 2015).

In English, Bleile (1996) documented key environments/phonetic environments in which speech sounds can be produced correctly based on clinical observations. He also suggested that individual variability exist in this regard. Table 2.3 shows the treatment targets and their respective key environments in general as given by Bleile (1996).

Table 2.3

Key environments for successful production of sounds in English (Bleile, 1996)

Treatment Targets	Key Environments	Example
All treatment targets	In CV, CVCV, or VC syllable context	**-**
All treatment targets	In stressed syllable contexts	**-**
Consonants	Beginning of the words	***Do***
Multiple consonants	A consonant made at a given place of production in a word with another consonant made at the same place of production.	***King and beep***
Voiced	Between vowels (voiced fricatives)/ beginning of syllables or words (voiced stops)	*Driver (voiced fricative)* ***Bee (voiced stop)***
Word initial position	Two-word phrase-first word ends with a consonant and the second word begins with a vowel. Beginning with vowel – silent /h/ +word	*It is* ***Heat***
Nasal consonants	Before a low vowel	***Mad***

Treatment Targets	Key Environments	Example
Alveolar consonants	Beginning of words before front vowels in the same syllable	***Tea***
Velar stops	End of word	*Peak*
	Beginning of words before a back vowel in the same syllable	***Go***
Voiced fricatives	Between vowels	-

Bleile (2006) also provided key environments for late acquiring sounds in typically developing children. The target sounds and their key environments are depicted in Table 2.4.

Table 2.4.

Late acquiring sound and their key environments (Bleile, 2006)

Treatment Targets	Key Environments	Example
/θ/	End of a syllable or word	*Teeth*
	Before high front vowel	***Thin***
/ð/	Between vowels	*Weather*
	Before high front vowel	***These***
/s/	End of a syllable or a word	*Bus*
	Before high front vowel	***See***
	After [t] and before [i]	*Pizza*
	After [t] occurring in the same syllable	*Beats*
/z/	End of a syllable or a word	*Fizz*
	Before high front vowel	***Zip***
	After [d] and before [i]	*Dzi*
	After [d] occurring in the same syllable	*Beads*

Treatment Targets	Key Environments	Example
/l/	Light /l/: Before high front vowel	***Leaf***
	Dark /l/: after a high back vowel at the end of a syllable	*Call*
Vocalic /r/	Word consisting single stressed syllable	*Girl*
Consonantal /r/	Before high front vowel	***Rid***
	Between vowels	*Creek*
	Syllable initial consonant velar cluster	
/ʃ/	End of syllable or word	*Fish*
	Before high front vowel	***She***
/ʧ/	End of syllable or word	*Batch*
	After high front vowel	*Witch*

Bauman-Waengler (2016) suggested the favouring vowel coarticulatory contexts for frequently misarticulated sounds and it shown in Table 2.5.

Table 2.5

Compatible and incompatible vowel contexts to teach error sounds (Bauman - Wangler, 2016)

Target sound	Compatible vowel/sound	Reason	Incompatible vowel/sound	Reason
[s] and [z]	[i], [ɪ], [ɛ], [e], [æ]	The sounds are phonetically comparable in terms of anterior position of the tongue with lip spread.	[u], [ʊ], [o], [ɔ]	Posterior tongue placement and lip rounding of the back vowels adversely affects the production of [s, z]

Target sound	Compatible vowel/sound	Reason	Incompatible vowel/sound	Reason
[ʃ] and [ʒ]	[i], [ɪ], [ɛ], [e], [æ]	If the error is faulty tongue placement, high front vowels facilitate the high front placement of tongue.	[u], [ʊ], [o], [ɔ]	Back vowels contradict with the anterior placement of tongue
[ʃ] and [ʒ]	[u], [ʊ], [o], [ɔ], [ɝ], [ɚ]	If the difficulty is with lip rounding, high back vowels and few central vowels with some degree of lip rounding	[i], [ɪ], [ɛ], [e], [æ]	Lip spreading prevents the establishment of lip rounding feature
[k]	[u], [ʊ], [o], [ɔ], [ɑ]	Elevation of posterior tongue in back facilitates the accurate placement of tongue required for [k], if the error is an anterior constriction.	[i], [ɪ], [ɛ], [e], [æ]	High front tongue placement of these vowels may revert back the faulty placement of the tongue.
[k]	[i], [ɪ], [ɛ], [e], [æ]	If velar sounds are substituted by postdorsal uvular, high front vowels are recommended.		

Target sound	Compatible vowel	Reason	Incompatible vowel	Reason
[g]	[ŋ]	The context of abutting consonant [ng] will be better than vowel context. Proceed from [g] to [k].		
[r]	Central vowel without r-coloring [ɑ] Back vowels	Produced with elevated mandibular position facilitates the production of [r] Facilitates the production of bunched [r] involving lip rounding feature as present in production of back vowels.	Front and back vowels	The posterior and anterior positioning of the tongue does not support the production of [r]
[l]	Low-back [ɑ], low-front [æ]	These vowel phonetic contexts are proposed to be used if visibility is important and when [w] is substituted for [l].	Mid-front vowels [ɛ], [e]; and high-back vowels [o], [ɔ].	Not recommended if [w] is substituted for [l], as these vowel contexts facilitate lip rounding which in turn facilitate production of [w] instead of [l].

Target sound	Compatible vowel	Reason	Incompatible vowel/sound	Reason
[l]	Back vowels	For [l] distortions as the concave posture of the tongue support relaxation of the lateral edges. Word final position facilitates dark [l]		
[l]	High-back vowels	Facilitates dark /l/ production. Sequence of vowels: high-back, mid-back, low-back, central, low-front, mid-front, and high front vowels.		
	High-front vowels	Aid in the production of light [l]. Sequence of vowels: high-front, mid-front, low-front, central, low-back, mid-back, and high-back vowels.		
[ð] and [θ]	High-front vowels [i], [ɪ], [ɛ], [e], [æ]	High front position of vowels facilitates the tongue placement for [ð, θ]. Vowel sequence: high-front, mid-front, low-front, central and later back vowels in the order from low to high.	High-back vowels [u], [ʊ], [o], [ɔ]	Posterior placement of tongue in back vowels is contraindicated.

Target sound	Compatible vowel/sound	Reason	Incompatible vowel/sound	Reason
[f] and [v]	High-front vowels [i], [ɪ], [ɛ], [e], [æ] and central vowel [ɑ]	Vowel sequence: high-front, mid-front, low-front, central and later back vowels in the order from low to high.	High-back vowels [u], [ʊ], [o], [ɔ]	The lip rounding feature is unfavourable for the establishment of [f].
[ʧ] and [ʤ]	High-front vowels [i], [ɪ], [ɛ], [e], [æ]	Anterior tongue placement of tongue in these vowels is similar to that of affricates. Vowel sequence: high to low front vowels followed by central and then back vowels.		
	High-back vowels [u], [ʊ], [o], [ɔ]	Favoured because of (1) lip rounding of high-back vowels (2) posterior movement of the tongue during back vowel production may enhance the backward gliding movement of the tongue during the transition from stop to fricative. Vowel sequence: high to low back vowels followed by central and then front vowels.		

In Indian languages, similar studies were carried out, and the first attempt was made in Kannada by Krishna and Manjula (1991). They reported that the production of retroflex /ʈ/ was facilitated in the context of vowels /a/ and /i/ for a 15-year-old male with misarticulation. Amulya (2018) investigated the facilitatory effect of vowel context and phoneme position in children with speech sound disorders in Kannada and the facilitating vowel contexts are summarized in table 2.6

Table 2.6

Facilitating vowel contexts and phoneme positions for specific speech sounds in Kannada (Amulya, 2018)

Phoneme	Mild to mildly moderate		Mildly moderate to severe	
	Facilitating vowel	Facilitating position	Facilitating vowel	Facilitating position
/k/	/a/	initial	/i/	Medial
/g/	variable findings		variable findings	
/ʈ/	/u/	initial & medial	/u/	initial & medial
/ɖ/	/u/& /a/	initial & medial	/a/	Medial
/ɳ/	/u/	Medial	/u/	Medial
/ɭ/	/i/ & /a/	Medial	/i/ & /a/	Medial
/ʧ/	/i/	Medial	/u/	medial
/ʤ/	/i/ & /u/	initial & medial	/i/& /u/	initial & medial
/s/	/i/	initial & medial	/i/	initial & medial

In Malayalam, a case study on facilitative vowel context for production of velar phonemes in children with hearing impairment revealed vowel /a/ facilitated the production of both voiced and unvoiced velars whereas vowel /e/ was the least facilitating context in Malayalam (Anu Rose & Sreedevi, 2017). This was attributed to the physiological fact that vowel /a/ is least coarticulatory resistant with velars based on ultrasound studies (Irfana, 2017).

2.1.3. Effect of Phoneme Position on Typical Speech Sound Development

Many developmental studies across the globe investigated the acquisition of phonemes with respect to position in the word. Branigan (1976) opined that initial position is advantageous for all consonants. The author opined "Consonants in initial position would receive the first neural commands and therefore be least influenced by preceding positions of the articulators" (p. 129). Other researchers also reported that a sound is easier to learn and should be taught in the initial-word position followed by the final-word position (Anderson & Newby, 1973; Van Riper & Emerick, 1984).

In English, most of the sounds are acquired earlier in the initial position when compared to the final position (Bleile, 2006; Dodd et al., 2003; Smith et al., 1990; Stoel-Gammon, 1985; Watson & Skucanec, 1997). In Arabic, speech sounds were achieved in medial position when compared to initial and final positions (Amayreh & Dyson, 1998) and in Quebecois French it is in the initial position followed by medial and final positions respectively (McLeod et al.,2011). Data on normal speech development in English showed that fricatives may be produced in word-final position before they are produced in word-initial position (Oller et al., 1976). In modern Chinese language Putonghua, syllable final consonants were acquired earlier than initial consonants (Hua & Dodd, 2000)

Gallagher and Shriner (1975), in their study on three normal children of 2 to 3 years 10 months having inconsistent /s/ and /z/ productions, observed that the phoneme /s/ was correctly produced in initial position, whereas /z/ in the final position. In contradiction to this, Kent (1982) reported the easy production of fricative /s/ in the word-final position compared to word-initial position. He reasoned that in the final-position, the influence of the neighbouring sounds in terms of articulatory adjustments is least and this is in accordance with the normal developmental sequence of fricatives (acquired in the final position before the initial position).

There have been inconsistent literature reports on the acquisition of North American English /r/ with respect to phoneme position. Few studies reported that liquid /r/ is acquired in the initial or prevocalic position (Curtis & Hardy, 1959; Hoffman et al., 1980; Magloughlin, 2016). On the other hand, more studies report that it is acquired in the final or postvocalic position compared to prevocalic position (McGowan et al., 2004; Stoel-Gammon, 1985; Smith et al., 1990; Templin, 1957).

Investigations on the early phonetic repertoire and syllable structure in Malayalam speaking children in the first fifty-word stage revealed that most of the consonants occurred in initial position compared to medial and final positions (Irfana & Sreedevi, 2012; Alphonsa & Sreedevi, 2012). On similar lines, studies were conducted in Kannada and it revealed an increased occurrence of bilabials and velars in the word initial position and palatals, dentals, and glottal in the medial position. Retroflex sounds occurred equally in both the positions (Shishira & Sreedevi, 2016; Sushma & Sreedevi, 2016).

Similarly, Divya and Sreedevi (2011) reported that /l/, /r/ and /n/ were first acquired in final position and /ɭ/, /ɲ/, /ʃ/, /d/, /r/, /s/ were first achieved in medial position, whereas /v/, /d̪/, /t̪/ and /j/ in initial position in Malayalam. Neenu and Sreedevi (2011) found that voiced velar stop /g/ and palatal nasal /ɲ/ were acquired earlier in initial position and voiced palatal affricate /dʒ/ was mastered in medial position in 3-4 year old children. Trills were mastered first in the final position. Medial clusters were mastered earlier in Malayalam (Neenu & Sreedevi, 2011; Vipina & Sreedevi, 2011; Vrinda & Sreedevi, 2011).

During the revision of Kannada articulation test Deepa and Savithri (2011) reported that certain phonemes were mastered earlier in certain positions and the trend was gender specific in Kannada. Girls as young as 2.6 years acquired stops, nasals and glides in both word initial and medial positions, whereas boys demonstrated a different trend. At the same age, boys could produce voiced stops in medial position and their unvoiced counterparts in initial position only. Palatal fricative /ʃ/ was acquired in the initial position, whereas dental fricative /s/ was acquired in the medial position. Medial clusters were earlier to acquire when compared to initial ones. Prathima and Sreedevi (2009) reported that /r/ was acquired earlier in medial position in Kannada.

2.1.4. Effect of phoneme position in clinical population

Clinical observations and various studies suggest that production of phonemes is facilitated more easily in particular phoneme positions (Curtis & Hardy, 1959; Houde, 1967; Bauman- Waengler, 2012; Shalini & Sreedevi, 2016). Scott and Milisen (1954) found that for the phonemes /f, v, k, g, r, 1, s, z/ all but /f/ and /z/ were produced correctly more often in the initial than in the medial and final positions of words. Curtis and Hardy (1959) described in a study of /r/ misarticulation in 30 children with functional misarticulation. They found that the intersyllabic /r/ (medial) was produced more correctly compared to /r/ in the initial or final position. Grundy (1995) mentions teaching /t/ in a word-final position in CVC words that begin with their alveolar consonants, or teaching /t/ in a word-final position because it does not require the additional load of aspiration that occurs on /t/ in word-initial position.

Numerous studies investigated the effect of phoneme position on the production of alveolar fricative /s/. In children with misarticulation, Mazza et al. (1979) investigated the production of /s/ and they documented 10 most facilitating contexts and 15 least facilitating contexts. Out of the 10 most facilitating contexts, all but one was having /s/ in word-final position. Of the 15 least facilitating contexts, only one was having /s/ in the word-final position. Hence it can be inferred that correct production of /s/ is facilitated in word final position. Rockman and Elbert (1984) observed that /s/ was acquired in the final position of words (syllable arrester) earlier than in the initial position (syllable releaser) in a 5-year-old child with phonological disorder. It has been reported that /s/ production is more likely to be correct in medial or final position than in initial position, except for certain initial clusters (Scott & Milisen, 1954; Spriestersbach & Curtis, 1951). Kent (1982) observed that word-final /s/ should be easier to produce than word-initial /s/ because (a) it is "minimally influenced by the articulatory requirements of surrounding sounds" and (b) normal articulatory development shows that fricatives may be produced in final position before they are produced in word-initial position. House (1981) reported that in final position, /s/ is produced better in consonant clusters than singletons. In contrast to this, Bennet and Ingle (1984) found that /s/ is easier to produce in initial position than medial or final position.

Later, Ghandour and Kaddah (2011) studied factors affecting stimulability of incorrect sounds in common types of dyslalia in 75 Arabic speaking children. The results revealed highest stimulability in the initial position followed by medial position and then final position as indicated by highest number of correct productions in initial position by children with good stimulability.

Facilitatory effect of phoneme position on correct production of phonemes had been negated by many researchers. Gallagher and Shriner (1975) reported that the correctness of /s/ and /z/ was not affected by the position of the sounds with respect to lexical boundaries or phonological acceptability of the sequences. Fleming (1971) reported that the facilitatory effect of initial or final position for a sound varies depending on whether the context is a syllable, word, phrase or a sentence.

Attempts were made to document effect of phoneme positions on production of phonemes in the Indian context. Shalini and Sreedevi (2016) observed that in Kannada, the production of trill /r/ was facilitated in the medial position compared to the initial position even in non-words in a child with speech sound disorder. Merin and Sreedevi (2017) studied the facilitatory effect of phoneme positions in correction of speech sounds in Malayalam speaking children with hearing impairment. Six children in the age range of 3-7 years with severe to profound hearing loss with misarticulations of affricates and fricatives were intervened. Results revealed that production of fricatives /s/ and /ʃ/ were facilitated in the initial position and affricates /ʧ/ and /ʤ/ in the medial position. These results were in agreement with the findings on typically developing children indicating that children with hearing impairment also follow the same pattern of acquisition. Amulya (2018) studied the combined effect of phoneme position and vowel context on correct production of phonemes in children with speech sound disorders in Kannada and the results of the same are summarized in the previous section (refer to table 2.6)

Effect of phoneme position on facilitating correct production of phonemes is inconclusive. Few opine that the correct production of a consonant in a word position is highly individualistic. Some individuals might find it easy to produce the error sounds in initial whereas others find it easy in final position (Fleming, 1971). Another viewpoint is that a person will more easily recognize his problem sound in a context if it occurs in an initial or final, rather than medial, position. Apparently, the subject notices and remembers most easily those elements which occur first or last in a sequence; elements elsewhere in the sequence may be overshadowed by those that come before or after them. Researchers also suggest that the generalization of correct production of a phoneme will be quick and spontaneous once a child can produce the sound correctly in a certain position (Powell & McReynolds, 1969). Hence it is important to obtain more research evidence regarding the effect of phoneme position especially in various clinical populations with speech sound disorders. Language specific data needs to be obtained as the phonotactics of languages differ. Few therapy approaches which emphasize on these factors will be discussed in the upcoming section.

2.2. Contextual approaches in articulation treatment

Few therapy approaches have been put forth based on contextual coarticulatory influences on correct production of a phoneme. Phonetic context approaches use the phonetic context or coarticulation in articulation treatment. The idea of key word was given by Van Riper (1972) and expanded by others (Mc Donald, 1964; Irwin & Weston, 1971). The use of facilitative vowel contexts draws on the traditions of articulation therapy (for example, Van Riper 1978), and some of the principles of integral stimulation therapy (for example, Strand & Skinner 1999), and phonotactic therapy (Velleman 1998, 2002). Some examples of using facilitative phonetic contexts are similar to the phonotactic approach advocated by Velleman (1998, 2002).

In sensorimotor approach, facilitating contexts are used to begin therapy at word level and they are very effective. A small core of words with an acceptable production can be employed to stabilize the production of target sound. Through this the client becomes aware of the tactile and kinesthetic aspects of speech sounds which can be gradually generalized to other contexts (Mc Donald, 1964). In paired stimuli approach, a word in which target sounds is correctly produced is used as a starting point and frame of reference. During the intervention, such key words are followed by training words (words in which target sound is erroneously produced). Motor based approaches also follow the developmental sequence.

Mc Donald (1964) recommends the use of facilitatory contexts during assessment and treatment of speech sound disorders. Knowledge of contextual factors including vowel context and phoneme position is important clinically for at least two reasons. First, with regard to assessment, a clinician who samples articulation of a given sound in a very limited number of contexts as is generally true of standard articulation testing and often true of informal assessment as well, should appreciate the effects context may have. To put the matter in an extreme light, a clinician might get quite different results from two different articulation screening tests if one test used exclusively facilitative phonetic contexts and the other used exclusively non facilitative contexts. These contexts are usually determined by detailed assessment of the stimulability of a particular sound. Miccio (2002) recommended a testing procedure where the error phoneme is probed for stimulability in isolation, three word positions for three vowel contexts (/a/, /i/, /u/).

The second reason is that management decisions could be based on the contextual sensitivity of correct sound production. That is, management would proceed from facilitative contexts to less facilitative or non-facilitative contexts.

Ideally, the clinician could work systematically through a hierarchical organization of facilitating conditions, including word or syllable position, stress, and adjacent vowels and consonants. In order for the notion of facilitative contexts to be useful in planning general training procedures, more consistent data would be necessary. The contexts need not only be identified but substantiated across children with speech sound disorders.

Individuals with intellectual disability exhibits speech sound errors and communication breakdown resulting from reduced speech intelligibility is a major problem in this population, it is important to establish facilitating contexts in them. Down syndrome (DS) is one of the common genetic disorders associated with intellectual disability. Hence the present study focuses on Down syndrome and the characteristics of the population is discussed in detail in the upcoming section.

2.3. Down syndrome

Down syndrome (DS) is considered as one of the most well-identified genetic syndromes which result in a wide variety of child developmental learning problems (Cantwell and Baker, 1987). It affects nearly one in every 800 births and it is the most common neurodevelopmental disorder resulting in intellectual disability (Dodd et al., 2005; Ypsilanti, et al., 2005). Biologically, Down syndrome is caused by an additional copy of chromosome 21 which is often known as Trisomy 21 (Dodd et al., 2005; Joffe & Varlokosta, 2007).

The diagnosis of DS can be made clinically on the basis of characteristics that may include generalized body hypotonia, flat facial profile, epicanthal folds, upslanting palpebral fissures, small nose, tendency toward profusion of tongue, developmental delay etc. Differences in brain structure including both central and peripheral nervous systems have been reported in individuals with DS. The brain size and weight are reduced with smaller and less number of sulci, narrower superior temporal gyrus and reduced number of cortical neurons. Reduced neuronal density, abnormal dendrite structure and altered cellular membranes along with delayed neuronal maturation have been reported in these individuals (Miller & Leddy, 1998; Rast & Harris, 1985; Yarter, 1980).

2.3.1. Language characteristics in children with Down syndrome

The cognitive phenotype of DS is characterized by a disproportionate deficiency in language development as opposed to social intelligence (Chapman et al., 1998). A significant delay in both speech and language is seen in individuals with DS (Abbeduto & Hagerman, 1997; Dodd, 1975; Kumin, 1996). The most consistently reported language profile in DS is one in which expressive language is more severely impaired than receptive language abilities (Grieco et al. 2015; Laws & Bishop, 2003; Rondal & Edwards 1997). Compared with their non-verbal cognitive level, individuals with DS are often significantly lower in expressive vocabulary, expressive syntax and receptive syntax (Abbeduto et al. 2003, Finestack et al. 2013). In contrast, they are often similar in receptive vocabulary to their non-verbal cognitive level (Naess et al, 2011). Speech intelligibility is poor relative to cognitive ability and is particularly pronounced in connected speech (Barnes et al., 2009; Naess et al. 2011; Roberts et al. 2007).

Delayed acquisition of first word and slow growth of expressive vocabulary is observed in this population (Berglund et al., 2001). Though early joint communicative behaviors such as mutual eye contact, vocalizations and dyadic interactions with caregivers are delayed than typically developing children, pragmatics is considered to be an area of strength in individuals with DS. Children with DS use a variety of communicative functions (comment, answer, protest) as a language or nonverbal ability-matched younger children, though they demonstrate fewer requesting behaviors (Beeghly et al., 1990). They also demonstrate high levels of contingent responding and topic maintenance (Beeghly et al., 1990).

The syntactic development in terms of comprehension and expression is slow in children with DS and it is more impaired than the overall cognitive ability and vocabulary size (Caselli et al., 2008). They produce short and less complex utterances with fewer questions/negation forms in comparison to the nonverbal mental age matched peers (Caselli et al., 2008; Price et al., 2007). In spite of relatively stronger receptive vocabulary, poor syntax skills compromise discourse comprehension, and affected expressive language skills often leading to production of simple statements that convey only basic meaning.

2.3.2. Oral structural characteristics and its impact on speech in children with Down Syndrome

Apart from language and cognitive deficits, structural and functional anomalies in the oral structures have been reported in individuals with DS. In terms of the oral skeletal structures, there are absent or deficient bone structures in individuals with DS. Poorly differentiated midface muscles (midface dysplasia) and/or additional facial muscles (Bersu & Opitz, 1980). Weakness in facial muscles including lips may result in impaired articulation of bilabials and rounded vowels. Prognathism is one of the oral manifestations of the disorder resulting in narrow oral and nasal cavities (Marder & Nunn, 2015). As a result of open mouth posture children with DS usually tend to breathe through the mouth and leave the mouth open with tongue straight behind the lips (Marder & Nunn, 2015). Dental anomalies include open bite, posterior crossbite, delayed eruption of teeth and missing teeth. The relatively small mouth and jaw in comparison to the size of the tongue results in a large tongue which protrudes forward (Kumin, 2008, 2012). They may also have high-narrow palate which may further constrain the tongue mobility. Reduced size of the oral cavity and a high palatal arch (Redman et al., 1965) may influence tongue placement for articulation of speech sounds including alveolar phonemes (Swift et al., 1988, Swift & Rosin, 1990; Kumin, 2008, 2012). Submucous clefts of the uvula and portions of secondary palate may occur more often among children with DS. Increased frequency of enlarged tonsils and adenoids are also observed in children with DS. Enlarged tonsils and adenoids can alter the resonance characteristics of speech adversely affecting speech intelligibility.

Functionally, such oral-motor abnormalities affect voice quality and resonance; besides they limit tongue mobility and shaping during speech production. The short neck stature is also associated with a more cephalic-placed larynx, and the shortened oropharyngeal structures are associated with nasal airway breathing difficulties (Gorlin & Pindborg, 1964; Vigild, 1985). Chronic upper respiratory tract infection is associated with blockage of the nasal cavity by mucus, leading to mouth breathing and lack of nasal resonance (Rondal & Edwards, 1997). There are also reports of drooling, open mouth posture, hypotonia, velopharyngeal insufficiency, and compromised respiratory support (Dodd & Thompson, 2001; Miller & Leddy, 1998). Children with DS have low muscle tone (hypotonia) (Rosenfeld-Johnson, 1997). That is, the muscles in the mouth (including lips, tongue and jaws) tend to be more relaxed so that they affect the mobility of articulators in the mouth and, in return, affect sound articulation. Children with DS may also show lip-tongue-jaw dissociation, i.e., they cannot move these parts independently which causes problems with coordination, accuracy and timing of movement. However, hypotonia may improve as the children grow older, but it may continue to certain degrees at later stages (Kumin, 2008, 2012; McDuffie & Abbeduto, 2009). Definitely, all these factors combined differently impact language development and phonology acquisition in particular with children with DS (Bernthal et al., 2009; Desai, 1997)

2.3.3. Speech characteristics of children with Down syndrome

Speech is considered as the most challenging difficulty which children with DS face during early life (Chapman et al., 1992; Dodd, 1975; 1976; Dodd et al., 1989; Dodd & Thompson, 2001; Kumin, 2006). The difficulty of developing speech in children with DS could be linked to their limited neurological abilities in coordinating speech articulators to produce meaningful speech (Buckley & Le Prevost, 2002; Dodd et al., 2005; Kumin, 2008; Kumin, 2012; Stoel-Gammon, 1997). A number of investigations on speech and language of individuals with intellectual disability have reported that articulatory/phonological problems are particularly severe for children with Down syndrome compared to other groups of intellectual disability (Blanchard, 1964; Dodd, 1975, 1976; Dodd, et al., 1989; Rosenberg & Abbeduto, 1993; Stoel Gammon, 1981).

2.3.3.1. Vowel errors

Vowel errors are noted in these individuals (Bunton et al.,2007; Van Borsel, 1996; van Bysterveldt et al., 2010). Children with DS were able to produce back vowel sounds correctly between the ages 9 months and 1;1 year (Dodd, 1972; Oller & Eilers, 1988). In their longitudinal study, Smith and Oller (1981) indicated that the children with DS aged 8 months and 4 days produced vowel qualities similar to those produced by their TD peers at the age of 8 months. Children with DS made fewer errors with vowels (Kumin, 2012; Stoel-Gammon, 1997; Van Bysterveldt et al., 2010; Stoel-Gammon, 1980). In a perceptual study of phonetic contrasts that are impaired in individuals with Down syndrome, Bunton et al. (2007) observed impaired contrast between high-low vowel and front-back vowel.

Acoustic studies revealed overlap in the first and second formant frequencies of different vowels leading causing confusions to the listeners (Novak, 1972). In support of this Bunton and Leddy (2011) observed a reduced acoustic vowel space area, reduced articulatory working space and reduced speed of articulatory movement for speakers with Down syndrome compared with the control speakers. These errors would have resulted from the constraints in regulating tongue height and advancement, due to the anatomic and physiological limitations. Accurate production of vowels requires precise tongue posture, control and timing and inappropriate tongue positioning has been shown to result in a compression of the acoustic vowel space or centralized vocal articulations (Weismer & Martin, 1992; Weismer 1997).

2.3.3.2. Consonant errors

Children with DS continue to exhibit reduced speech intelligibility in varying degrees compared to their typically developing peers (Kumin, 2006; Kumin et al., 1994; Pueschel & Hopmann, 1993). The consonant errors exhibited by individuals with DS are comparatively lesser that their vowel, liquid and glide errors (Bunton et al., 2009). They exhibit errors in phonetic contrasts involving tongue posture, control, and timing (place of articulation for stops and fricatives) (Bunton et al., 2007). Production of fricatives, affricates and liquids are affected compared to stops, nasals and glides (van Bysterveldt et al., 2010; Bleile & Schawrtz, 1984; Smith, 1984; Stoel Gammon, 1980; Stoel-Gammon, 1983).

Stoel-Gammon (1980) studied the accuracy of production of phonemes in children with DS. The findings revealed that the children were able to produce consonants correctly in specific word positions. Stops are nasals were produced correctly in all three word positions (initial, medial & final positions). However, velar nasal /ŋ/, fricatives /θ, ð/ was errored in all the word positions. Bleile (1982) studied the organization of phonemes in a 4-year child with DS. The child had a constrained forward-backward consonant ordering that in CVC words the initial consonant should either be identical to the final consonant (e.g. 'cup' [kʌp] produced as [bɜ:p]) or articulated at the front part of the mouth (e.g. 'cheek' [ʧi:k] produced as [di:k]). The study revealed that the consonant ordering accounted for the consonant substitutions the child produced. This led to conclude that the child with DS had actively imposed specific structure on sound production.

The acquisition of consonant clusters tended to be more delayed for children with DS compared to mental age matched typically developing children (Dodd, 1976; Dodd & Thompson, 2001; Iacono, 1998; Roberts et. al., 2005; Stoel-Gammon, 1997). Studies using single word and conversational samples revealed that most frequent cluster errors were cluster reduction (e.g., /skw/ in square reduced to [weə]), or cluster simplification in which one of the cluster constituents replaced by a glide /w/ (e.g., /kl/ in clean simplified to [kwi:n] (Barnes et al., 2009; Iacono, 1998; Roberts et al., 2005). The frequency of cluster errors were more than their TD peers when the two groups were matched for mental age. Children with DS who have phonological problems usually have difficulty producing consonant clusters (Chin & Dinnsen, 1991; Hodson & Paden, 1981; Powell & Elbert, 1984; Stoel-Gammon, 1987).

Children with DS tend to continue cluster reduction errors longer compared to mental age matched typically developing children (Hodson & Paden, 1981; Wyllie-Smith et al., 2006). Therefore, cluster reduction process lasted for longer time to be reduced, and finally eliminated.

2.3.3.3. Phonological processes

The phonological processes persist longer than typically developing children in children with DS (Bodine, 1974; Bleile & Schwarz, 1984; Dodd, 1976). The most common phonological processes used by children with DS between the ages of 3 and 4.6 years includes final consonant deletion, cluster reduction, and stopping (Bleile & Schwarz, 1984). In addition to these processes, vocalization of word final liquids and gliding in word initial position and devoicing were also reported (Dodd, 1976; Stoel-Gammon, 1980, 1981; Mackay & Hodson, 1982; Smith & Stoel Gammon, 1983; Cholmain, 1994; Kumin et al., 1994; Van Borsel, 1996). Dodd (1976) compared the phonological system of children with Down syndrome with typically developing children and children with learning difficulties. It was found that the DS group exhibited greater number of phonological errors which were inconsistent in nature and these errors cannot be described using the common set of phonological processes.

2.3.3.4. Speech motor control

Some individuals with DS exhibit deficits in oral motor skills and/or oral motor planning. These skills refer to strength and movement of the oral facial muscles, especially movements related to speech. Oral motor planning skills refer to the ability to combine and sequence phonemes into words, phrases and sentences. Deficits in oral motor skills and oral motor planning adversely affects speech intelligibility in this population. Numerous studies examining the nature of the difficulty with oral motor skills and oral motor planning in typically developing children have been conducted (e.g. Shriberg et al.,1997; Davis et al.,1998; Caruso & Strand, 1999; Strand & McCauley, 1999; Strand & Skinner, 1999; Forrest, 2003). Although the presence of these impairments has also been observed clinically in children with Down syndrome, few studies in the research literature describe the problems with oral motor skills/planning in this population.

A reduced DDK rate was observed in individuals with DS (Brown-Sweeney & Smith, 1997; Hamilton, 1993; Swift et al., 1988), but there are reports of diadochokinetic rate comparable to that seen in typically developing children, even though there were more inaccuracies in performance in individuals with DS (McCann & Wrench, 2007). Fawcett and Peralego (2009) reported that the speech of individuals with DS is characterized by a rapid rate of speech although this finding is not universal. Apraxia of speech has also been reported in DS (Rupela & Manjula, 2007).

2.3.3.5. Phonological development in children with DS

Generally, the phonological development in children with DS is interdependently correlated with speech sound acquisition and connected speech development at later stages in life. Extensive normative data on phonological development in children with DS have been obtained and analyzed (e.g. Anthony et al., 1971; Chirlian & Sharpley, 1982; Dodd et al., 2003; Kilminster & Laird, 1978; Prather et al., 1975; Robb & Bleile, 1994; Smith et al., 1990). It has also been emphasized that there is a need to develop research about phonological development in children with DS and how speech sound acquisition and production accuracy affect speech development in DS population (Buckley & Le Prevost, 2002; Iacono, 1998, Kumin, 1986; Kumin et al., 1994; Pueschel & Hopmann, 1993, Stoel-Gammon, 1980, 1997).

The prelinguistic phonological development is in par with typically developing children whereas the onset of meaningful speech is considerably delayed in children with DS (Smith & Oller, 1981; Smith & Stoel-Gammon, 1996; Dodd, 1972). Studies revealed that most speech sound errors are developmental in nature (e.g., cluster reduction and final consonant deletion) though some atypical errors are also evident, such as vowel distortions and inconsistent pronunciations (Cleland et al., 2010). The order of acquisition of phonemes in children with DS is slightly deviant from that of the typically developing children (Kumin et al., 1994). In the Indian context, it has been reported that the order of acquisition of phonemes in children with mental retardation was similar to typically developing peers in Odiya language (Panda, 1991).

Rupela and Manjula (2007) investigated the phonotactic patterns of individuals with DS in Kannada and they found an increased proportion of disyllabic words, medial geminated clusters, VC syllable shape compared to the typically developing peers. The oral motor, oral praxis and verbal praxis skills were also studied in these children in Kannada (Rupela & Manjula, 2008). Deficits in tongue and jaw positioning were noticed which may be due to the hypotonia of jaw and tongue. Tongue thrust was observed in 20% of the individuals with DS. Building intraoral breath pressure and precision of fricatives and stops and velopharyngeal functions were most frequently affected in individuals with DS compared to the typically developing children and children with mental retardation (without DS). Range of movement for the tongue and jaw are affected in these children. The oral praxis and verbal praxis skills were affected in a subgroup of these children which could not be attributed to the anatomical abnormalities and sluggishness of movements.

In a nutshell, the phonological acquisition in children with DS proceeds at a slower pace (Dodd et al., 1989; Rosenberg & Abbeduto, 1993) and it is more variable (Stoel-Gammon, 1981). A greater proportion of idiosyncratic and/ or atypical speech errors are also observed in them (Dodd, 1976). Differences in development of suprasegmental features of speech have also been observed (Moran & Gilbert, 1982; Pentz & Gilbert, 1983; Shriberg & Widder, 1990; Weinberg & Zlatin, 1970).

2.3.3.6. Speech intelligibility in DS

Reduced speech intelligibility is a major challenge for communication in children with DS. They exhibit both typical and atypical phonological deficits which adversely affect the speech intelligibility (Shriberg & Widder, 1990; Stoel-Gammon, 1997). Parental reports suggest that speech of children with DS is difficult to understand for people apart from the immediate family including friends, acquaintances as well as teachers (Kumin, 2006; 2012).

In a questionnaire-based study conducted by Kumin (2006), reports were collected from 937 parents of children with DS (age range 1;0-21;0, mean age 8;16 years). About 60% of the parents reported that their children's speech as unintelligibile and they constantly encounter difficulty to understand children's utterances. On the other hand, 37% of participating parents reported that they were sometimes unable to understand their children's utterances. According to the responses of 80% of participating parents, most of the speech intelligibility problems resulted from articulation difficulties. In another questionnaire-oriented study, Pueschel and Hopmann (1993) revealed that 71% to 94% of parents of children with DS aged between 4;0 and 21;0 years attributed their children's intelligibility problems to articulation and the inability to produce phonemes in the correct context (phonological problems).

According to Stoel-Gammon (1997; 2001) and Roberts et al. (2007), producing intelligible speech remained to be the main lifelong communication barrier for children with DS when compared to TD children who tended to be approximately fully intelligible by the age 4;0 years. At younger ages, speech of children with DS was unintelligible and with advance in age they started to produce one-to-two-word utterances which were intelligible. But connected speech tasks like a conversation about a day at school continued to be unintelligible (Bray & Woolnough, 1988; Martin et al., 2009). Bray and Woolnough (1988) investigated the speech intelligibility in 11 children with DS aged between 12;0 and 16;0 years. They reported that there is an inverse relation between speech intelligibility and syntactic complexity, i.e. as the syntactic complexity of the utterances increased speech intelligibility reduced. Speech intelligibility and understandability levels depended on the type of the conversational topic and the closeness of the relationship with the listener (Kumin, 2006; 2008; 2012).

Children with DS have oral structural and functional deficits that can interfere with intelligible speech production. These physical characteristics combined with low muscle tone in the tongue, lips, and cheeks contribute to the difficulty children with DS have in producing the precise sounds and sound combinations required for intelligible speech (Kumin, 1996; Spender et al., 1995;1996). Complications arising from frequent bouts of middle ear infection also add on to the severity of speech sound errors in children with DS (Martin et al., 2009). Such phonological/articulatory errors have a negative impact on speech intelligibility which is further documented as a major concern of parents and caregivers of individuals with DS (Kumin, 1994;

Pueschel & Hoppmann, 1993). This emphasizes the need to target speech intelligibility of children with DS during speech and language intervention. However, speech-language pathologists and educators working with children and adults with Down syndrome have focused less on problems with speech and its intelligibility during intervention programs (Kumin, 1986). At least four primary influences have been implicated in the overall communication difficulties of the Down syndrome population: (a) hearing deficits, (b) oral motor problems, (c) altered language environment, and (d) deficits in cognitive domains that are associated with language learning (Miller, 1987).

2.4. Remediation of speech sound errors in Down syndrome

The ultimate goal of majority of intervention programs is to equip persons with DS to live independently and work in the community. In terms of speech and language intervention, the goal is to increase the basic communication skills essential for social interactions and vocational training. As children with DS often have diminished speech intelligibility (Swift et al., 1988) and the problem does not appear to be outgrown with age (Horstmeier, 1987), it is, therefore, a remediation issue. Thus, individualized speech intervention programs need to be planned and tailored to the needs of each individual child with DS. However, the decision-making process regarding the selection of a suitable intervention program is not easy, as it needs substantial effort to understand each child's phonological system and needs. Continuous research in addition to clinical practice and the children's characteristics and needs are considered as the most informative factors that could support speech-language therapists (SLTs) during the decision-making process (Kamhi, 2006).

Most of the previous research agreed that, in the light of information obtained from research on phonological development in children with DS, various individualized speech intervention programs targeting speech could be designed for children with DS in order to improve sound production accuracy and increase speech intelligibility (Buckley & Le Prevost, 2002; Stoel-Gammon, 2001). According to Swift and Rosin (1990), there was limited intervention programs designed to target phonology-oriented speech difficulties for children with DS. Few studies used operant conditioning to increase the vocal/verbal output of children with Down syndrome (MacCubrey, 1971; Salzberg & Villani, 1983). A literature search revealed only three papers which specifically discussed improving speech in the Down syndrome population.

Cholmain (1994) described a therapy program for children with DS (4;1 - 5;6 years) which used listening and production practices focusing on error phonemes and phonological processes, which was based on cycles approach by Hodson and Paden (1983). In this 6-14 weeklong therapy program, significant improvement in Percentage of Consonants Correct (PCC) measures and use of grammatical forms was documented in the participants. In another study, Dodd et al. (1994) conducted a 12-week parent directed treatment program focusing on reducing the variability in word productions. The children demonstrated improved speech intelligibility post-treatment and produced fewer deviant and developmental errors. In the other study, Broad Target Speech Recast (BTSR) was implemented with children who had DS and an average chronological age of 5.1 years. The results of this multiple-baseline across-participants experimental design supported an inference that there was a functional (i.e., causal) relation between the BTSR treatment and increases in generalized speech comprehensibility in four of six participants with DS (Camarata et al., 2006). Improvement in speech comprehensibility was noted after the therapy program.

In some other studies, it was argued that in spite of the significance of communication skills intervention programs to develop the children's daily life, the need to enhance the children's phonological skills via developing phonology-based treatment models should be considered (Shriberg & Widder, 1990). Research suggests that the speech intelligibility of children with DS improves with intervention, but their learning pace was reported to be slow (Cholmain, 1994; Dodd et al.,1994). Shriberg and Widder (1990) argued that correction of the articulatory errors should be a mandatory goal during the intervention of children with DS, though the progress is slow, and the resources are limited. Improving speech intelligibility will enhance the social and vocational placement of individuals with intellectual disability. This stresses the need to consider numerous factors while designing intervention goals for children with DS.

For many persons with an intellectual disability, communication breakdown resulting from reduced speech intelligibility is a major problem. As it allows the exchange of needs and feelings, facilitates thinking and contributes to developmental and learning processes, communication by speech is an important part of social and mental well-being, and a lack of verbal communication may lead to diminished social skills, behavioural problems and isolation (Bott et al.,1997). Given that verbal communication constitutes the main means of communication for people with intellectual disability, especially mild and moderate intellectual disabilities (Bradshaw, 2001; Healy & Noonan Walsh, 2007; McConkey et al., 1999; Roberts et al., 2007), it is essential that they are able to make themselves understood through speech. The development of assessments to evaluate and interventions to improve speech production and intelligibility in this population are thus indispensable. By investing in improving the quality of their speech, one can improve communication and, by extension, their quality of life in general. Hence it is important to take up intervention of articulatory skills as part of speech and language intervention.

Many approaches have been suggested for the intervention of articulation like traditional, motor placement, tactile-kinesthetic, phonetic context etc. An appropriate stimulus hierarchy considering the facilitating coarticulatory contexts can be tied up with any of these approaches to yield better results. Contextual and positional preferences to teach a particular sound have been dealt in a number of studies in the western literature (Bauman -Wangler, 2012; Bennet & Ingle, 1984; Bleile, 2004; Gallagher & Shriner, 1975; Scott & Milisen, 1954), but such studies are not attempted in the Indian context.

In the Indian context, articulation therapy for children with Down syndrome is seldom conducted using the facilitating contextual and positional effect as such information has not been documented. Hence a systematic study in this direction will give more insight regarding the underlying patterns involved in this. Thus, a hierarchy of facilitating contexts and positions can be obtained so as the intervention goals can be planned according to this. It will be helpful in reducing the time and effort involved in the speech remediation process of DS. With this insight the present study aims at identifying specific vowel contexts and phoneme positions which facilitate the correct production of target phonemes in children with Down syndrome in Malayalam.

Chapter 3: Methods

The present study aimed to investigate the effect of vowel contexts and phoneme positions in facilitating the correct production of phonemes by children with Down syndrome in Malayalam.

3.1. Study design

The present study was a single subject study and the research design used was AB design. As discussed about AB design in section 1.2, pre-therapy baseline scores were obtained for vowel contexts and phoneme position for each target phoneme. The independent variables considered in the study was vowel contexts (/a/, /i/, /u/, /o/ & /e/) and phoneme positions (initial & medial). Percentage of correct production was measured continuously throughout the intervention and the progress of participants in each vowel context and phoneme position were monitored.

Single-subject designs may typically include one participant or multiple participants (e.g., 3 to 8) in a single study (Horner et al., 2005). In the present study though 15 children with DS served as participants, the number of participants selected for intervention for each phoneme ranged from one to five. Hence it is deemed as a single subject design.

3.2. Procedure

The study was carried out in four phases.

Phase 1- Preparation of stimuli for assessment and intervention

Phase 2- Pilot study

Phase 3- Establishment of facilitating vowel context and phoneme position using articulation therapy

Phase 4- Validation of the results

The study was approved by the ethics committee for bio-behavioural research projects involving human subjects, All India Institute of Speech and Hearing, Mysore, India. The study adhered to the ethical guidelines proposed by Basavaraj and Venkatesan (2009).

3.2.1. Phase 1- Preparation of stimuli for assessment and intervention.

To identify the facilitating vowel contexts and phoneme positions, words with the target phonemes occurring in the context of the vowels /a, i, u, e, o/ in the initial and medial positions were selected. Two wordlists were prepared for assessment and intervention of ten commonly misarticulated phonemes in Malayalam (Rofina & Sreedevi, 2018). The target phonemes considered are listed below and the corresponding Malayalam graphemes are provided in Appendix II.

1. Unvoiced retroflex stop /ʈ/
2. Voiced retroflex stop /ɖ/
3. Retroflex nasal /ɳ/
4. Retroflex lateral /ɭ/
5. Unvoiced retroflex fricative /ʂ/
6. Retroflex approximant /ʐ/
7. Unvoiced alveolar fricative /s/
8. Alveolar tap /r/
9. Alveolar trill /ṛ/
10. Unvoiced velar stop /k/

Vowel contexts and phoneme positions were selected based on the occurrence of phonemes in the language. Retroflex nasal (/ɳ/), approximant (/ʐ/) and lateral (/ɭ/) does not occur in initial position in Malayalam as per the phonotactic rules of the language. Hence words were selected only in medial position for these phonemes. For the remaining seven phonemes, words were selected in both initial and medial positions. Simple meaningful, bisyllabic or trisyllabic Malayalam words from textbooks of primary grades, dictionaries and loan English words from general conversations of native speakers of Malayalam were selected. The words were rated for familiarity by three speech-language pathologists who were native speakers of Malayalam on a three-point rating scale from '0' to '3', where '0' indicated 'not familiar', '1' indicated 'familiar' and '2' indicated 'very familiar'. The words rated as familiar or very familiar by at least two judges were selected as stimuli for the study.

The number of stimuli words varied across different target consonants as the vowels considered in each consonant context varied. The intervention word list consisted of minimum of two and maximum of three words per vowel context whereas the assessment word list consisted of one word each for vowel context and phoneme position. The assessment and intervention wordlists for the 10 phonemes are provided in Appendix III. A set of three pictures were selected for each target stimulus from google images considering its familiarity, ambiguity, clarity, and appropriateness to the Indian context. The pictures selected for each word were rated for acceptability by three speech language pathologists on a 3–point rating scale from '0' to '2' for familiarity, clarity, ambiguity, iconicity, and naturalness. The pictures which were rated as acceptable (score of 1) and most acceptable (score of 2) by at least two out of three speech language pathologists were chosen as the stimuli.

A total of 61 words were selected for assessment wordlist and 160 words for intervention wordlist for a total of 10 target phonemes. The number of words in assessment and intervention wordlist for the ten phonemes are listed in Appendix IV. The final intervention wordlist for each phoneme was randomized with respect to vowel context and phoneme position in order to eliminate the effect of word order. Power Point slides with the picture and orthographic form of the words were prepared for each target phoneme based on the randomized word list.

3.2.2. Phase 2- Pilot study

A pilot study was conducted on three participants diagnosed as Down syndrome with mean chronological age of 8.8 years. They were recruited from the Department of Clinical Services, and Department of Special Education at the All India Institute of Speech and Hearing, Mysuru. The aim of pilot study was to determine the number of articulation therapy sessions required to achieve 80% correct production in at least one of the vowel contexts for various target phonemes in DS. Malayalam Diagnostic Articulation Test - Revised (Neenu et al., 2011) was administered to identify the error phonemes before the intervention. Demographic details and articulatory profile of the participants are as shown in table 3.1.

Table 3.1.

Demographic details and articulatory profile of DS participants of pilot study

	Participant 1	**Participant 2**	**Participant 3**
Age	10:1 years	8:3 years	8:1 years
Gender	Male	Female	Male
IQ	40	55	49
Severity of ID	Moderate	Mild	Moderate
Articulatory errors (No. of errors)	l/ɭ, d̪/ɖ, t̪/ʈ, n/ŋ, n/ɲ, d̪/dʒ, t̪/dʒ, j/r, j/ʐ, j/ɽ (10)	ʃ/s, j/ʐ, j/r. j/ ɽ (8)	l/ɭ, n/ɳ, j/ɽ, j/r, j/ʐ, s/ʃ, l/ɽ (8)
Target phoneme	/ʈ/ & /ɖ/	/s/	/ɭ/ & /ɳ/

Note. IQ = intelligence quotient, ID = intellectual disability

Based on the errors identified, /ʈ/ and /ɖ/ were selected for intervention for participant 1, /s/ for participant 2, and /ɭ/ and /ɳ/ for participant 3. Target phonemes were determined based on the order of acquisition of phonemes in typically developing children (Neenu et al., 2011). Intervention wordlists prepared for the respective phonemes were used for therapy and the words were presented in two random orders to the participants. Number of sessions required for intervention to meet 80% of correct production in at least one of the vowel contexts was documented. Table 3.2. Shows the facilitating vowel context and number of sessions essential to achieve the same.

Table 3.2

Facilitating vowel context and phoneme position and number of sessions required for achieving correct production in participants of pilot study

Participant No.	Phoneme	Facilitating context	Phoneme position	No. of sessions
1	Unvoiced retroflex stop /ʈ/	/o/	Medial	8
	Voiced retroflex stop /ɖ/	/i/	Medial	8
2	Alveolar fricative /s/	/i/	Initial	9
3	Retroflex lateral /ɭ/	/u/	Medial	7
	Retroflex nasal /ɳ/	/a/	Medial	8

The average number of sessions required for the participants to achieve 80% correct production was eight. Hence the number of sessions for each phoneme was finalized as ten considering two additional sessions to check the consistency of production. Participants were able to sustain attention when the wordlist was presented twice. Hence in phase 3, two random orders of presentation of wordlist were retained.

3.2.3. Phase 3-Establishment of facilitating vowel context and phoneme position using articulation therapy

In phase 3, the vowel contexts and phoneme positions that facilitated the correct production of various phonemes in Malayalam were established. Information on the participants and procedure followed for the same will be discussed under the following heads.

- Participants
- Stimuli
- Pre intervention assessment of articulatory skills
- Intervention procedure
- Data analyses
- Statistical analyses

3.2.3.1. Participants

A total of 31 children with Down syndrome in the age range of 7-13 years were assessed to determine candidacy for the study. They were selected from three special schools for children with intellectual disability in Kerala. The participants who met the following inclusion criteria were shortlisted for detailed assessment of articulatory skills.

- Native speaker of Malayalam.
- Diagnosed as Down syndrome by a Paediatrician.

- Mild to moderate degree of mental retardation based on non-verbal psychological testing.
- Mean length of utterance (MLU): A minimum of 2-3 words based on 3-Dimensional Language Acquisition Test (Harlekhar & Karanth, 1986)
- Speech intelligibility less than 80% which was calculated from a conversational sample using the formula

$$Speech\ intelligibility = \frac{Number\ of\ intelligible\ words}{Total\ number\ of\ words\ uttered} X\ 100$$

Children identified with any dental anomalies, peripheral hearing problems, history of middle ear infections, significant visual impairments, co morbid conditions of autism, cerebral palsy, seizures, other developmental disabilities or severe behavioural problems were excluded from the study.

A total of 16 children were excluded from the study due to numerous reasons (4 children with no consistent substitution errors; 1 child with severe hypotonia; 2 children with suspected childhood apraxia of speech; and 2 children who were non cooperative for the therapy procedure; 7 children with insufficient language skills). A total of 15 children (7 males & 8 females) with Down syndrome (mean chronological age: 10:4 years, mean IQ: 52.53, mean mental age: 4:8years) were recruited for phase 3 of the study. Severity of intellectual disability was determined based on IQ (DSM IV-TR, 2000) and the scale is provided in Appendix V. The demographic details of the participants are as shown in table 3.3.

The participants were enrolled in special school for approximately three to five years and received speech and language therapy in the school. The frequency of sessions ranged from one to three sessions per week. However, articulation skills were not consistently worked upon in the participants prior to recruitment for the study. During the data collection of the current study, speech language pathologists in the schools were instructed not to work on articulation goals.

Table 3.3.

Demographic details of the DS participants

Sl. No	Participants	CA (in Years: Months)	Gender	IQ	Severity of ID	MA (in Years: Months)
1.	Nj	8:3 years	Male	55	Mild	4:7 years
2.	Ak	8:1 years	Male	49	Moderate	4 years
3.	Ny	10:3 years	Female	49	Moderate	5:2 years
4.	Kj	11:6 years	Female	45	Moderate	5:5 years
5.	An	10:3 years	Male	50	Mild	5 years
6.	Sd	8 years	Male	45	Moderate	4 years
7.	Sh	9:1 years	Male	46	Moderate	4:2 years
8.	Hd	10:10 years	Female	55	Mild	5:5 years
9.	Fm	9:1 years	Female	55	Mild	5 years
10.	Sj	10:5 years	Male	60	Mild	6 years
11.	Ma	8.5years	Female	60	Mild	5:1 years
12.	Es	7.6 years	Female	60	Mild	4:5 years
13.	Sc	10 years	Male	49	Moderate	4.9 years
14.	El	12:5 years	Female	50	Mild	6.3 years
15.	Dn	12:1 years	Female	60	Mild	6:5 years

Note. CA=Chronological Age, IQ= intelligence quotient, ID= intellectual disability, MA= mental age

3.2.3.2. Stimuli for assessment and intervention

Wordlists prepared during phase 1 were used as stimuli for the study. Assessment wordlist was used to obtain the baseline of articulation in each of the vowel context and intervention wordlist was used for therapy. As two random orders of presentation of stimuli words were found to be feasible during pilot study, it was retained in this phase as well. Two wordlists were prepared by randomizing words in the intervention wordlist of each phoneme with respect to vowel context and phoneme position. Randomization was carried out to eliminate the effect of word order on learning the correct articulation of a phoneme. Power Point slides with the picture and orthographic form of the word were prepared for each target phoneme based on the randomized wordlist.

3.2.3.3. Pre intervention assessment of articulatory skills

The articulatory skills of the selected participants were assessed using Malayalam Diagnostic Articulation Test - Revised (Neenu et al., 2011). Responses of participants were transcribed using broad phonetic transcription (International Phonetic Alphabet, 2015) by the researcher. Speech sound errors were identified and classified as substitution, omission, distortion and addition errors. The major type of errors were substitutions, omissions and distortions with no addition errors. Substitution errors were the most frequent type of articulatory error. Omission errors were predominantly seen as cluster reductions and correction of clusters was not in the purview of the study. Distortion errors are difficult to correct in children with DS due to the functional deficits. Hence phonemes with consistent substitution errors which impacted the speech intelligibility to a greater extent were selected for articulation therapy. Severity of speech sound disorder was determined using

Percentage of Consonants Correct- Revised (PCC-R, Shriberg et al., 1997). The stimuli words in Malayalam Diagnostic Articulation Test – Revised (Neenu et al., 2011) were used for calculating PCC-R and the formula for the same is given below

$$PCC - R = \frac{\text{Number of consonants correct}}{Number\ of\ consonant\ targets} \times 100$$

Speech intelligibility was rated on a five-point rating scale (Bowen, 2009) and is provided in Appendix VI. Inter personal and intra personal discrimination abilities of the participants were also documented and the procedure for the same is described in Appendix VII. Each participant's profile on articulatory errors, error consistency, speech intelligibility, intrapersonal and interpersonal discrimination abilities and severity of the problem are provided in Table 3.4.

Table 3.4

Articulatory profile of the participants

Sl. No	Participants	Substitution errors	Error Consistency	Intelligibility (Bowen, 2009)	Inter person discrimination	Intra person discrimination	Severity (PCC-R)
1.	Nj	d/ɖ, t/ʈ, j/r, l/r, j/ṛ, j/ʐ, n/ɲ (7)	Consistent	3-somewhat intelligible in conversation	Good	Fair	Moderate (53.85%)
2.	Ak	l/ɭ, t/ʈ, n/ɳ, j/ṛ, j/r, j/ʐ, s/ʃ, l/ṛ (8)	Consistent	4-mostly unintelligible in conversation	Good	Fair	Moderate (53.85%)
3.	Ny	n/ɳ, t/s, j/ʐ, j/r, j/ṛ (5)	Consistent	4-mostly unintelligible in conversation	Fair	Poor	Severe (44.76%)
4.	Kj	t/k, d/g, t/s, c/ʂ, k/r, ɭ/r, j/r, j/ʐ (8)	Consistent	3-somewhat intelligible in conversation	Good	Fair	Moderate (58.04%)
5.	An	n/ɳ, l/ɭ, n/ɲ, j/r, j/ṛ, j/ʐ, ʃ/ʂ (7)	Consistent	3-somewhat intelligible in conversation	Good	Good	Moderate (60.14%)

Sl. No	Participants	Substitution errors	Error Consistency	Intelligibility (Bowen, 2009)	Interpersonal discrimination	Intrapersonal discrimination	Severity (PCC-R)
6.	Sd	l/ɭ, ʈ/ɖ, l/ṛ, l/r, j/ʐ, s/ʂ, n/ɳ (7)	Consistent	3-somewhat intelligible in conversation	Good	Good	Moderate (64.34%)
7.	Sh	n/ɳ, j/r, c/s, d/ɖ, l/ṛ, j/ṛ, j/ʐ, t/ʈ (7)	Consistent	4-mostly unintelligible in conversation	Good	Fair	Moderate (52.45%)
8.	Hd	n/ɳ, l/ɭ, d/r, t/ʈ, n/r, j/ṛ, d/ɖ, j/r, j/ʐ (9)	Consistent	3-somewhat intelligible in conversation	Good	Fair	Mild to moderate (68.53%)
9.	Fm	n/ɳ, d/ɖ, p/b, j/r, j/ṛ, ʃ/s, ʈ/ɖ, j/ʐ, d/ɖ (8)	Consistent	3-somewhat intelligible in conversation	Good	Good	Moderate (63.64%)
10.	Sj	n/ɳ, j/l, j/ɭ, d/ɖ, t/ʈ, l/r, n/ɲ, j/ṛ, s/ʃ, j/ʐ, s/ʂ (11)	Consistent	2-mostly intelligible in conversation	Good	Good	Mild to moderate (58.04%)

Sl. No	Participants	Substitution errors	Error Consistency	Intelligibility (Bowen, 2009)	Interpersonal discrimination	Intrapersonal discrimination	Severity (PCC-R)
11.	Ma	d/r, ɖ/ṛ, j/ʐ, c/ʂ, c/s (5)	Consistent	2-mostly intelligible in conversation	Good	Good	Mild to moderate (75.52%)
12.	Es	j/r, j/ṛ, j/ɻ (3)	Consistent	2-mostly intelligible in conversation	Good	Good	Mild to moderate (77.62%)
13.	Sc	c/ʂ, j/ṛ, j/ʐ, c/ʃ (4)	Consistent	4-mostly unintelligible in conversation	Good	Fair	Moderate (56.64%)
14.	El	j/ɻ (1)	Consistent	2-mostly intelligible in conversation	Good	Good	Mild to moderate (78.32%)
15.	Dn	j/ɻ (1)	Consistent	2-mostly intelligible in conversation	Good	Good	Mild (88.87%)

PCC-R- Percentage of Consonants Correct-Revised

Based on the speech sound errors identified in the participants, the following ten phonemes were selected for intervention.

1. Unvoiced retroflex stop: /ʈ/
2. Voiced retroflex stop: /ɖ/
3. Retroflex nasal: /ɳ/
4. Retroflex lateral:/ɭ/
5. Unvoiced retroflex fricative: /ʂ/
6. Retroflex approximant: /ʐ/
7. Unvoiced alveolar fricative: /s/
8. Alveolar flap: /r/
9. Alveolar trill: /ṛ/
10. Unvoiced velar stop: /k/

The order of the target phonemes for intervention was decided based on the following criteria:

- Phonetic developmental sequence based on the norms of Malayalam Diagnostic Articulation Test-Revised (Neenu et al., 2011).
- Unvoiced phonemes were chosen for intervention prior to their voiced cognates as unvoiced ones are acquired earlier (Bowen, 2009).
- Frequently misarticulated phonemes in Malayalam (Rofina & Sreedevi, 2018).

Order of target phonemes for each of the participants are as shown in Table 3.5.

Table 3.5.

Order of target phonemes considered for intervention in each participant

Sl. No	Participants	Order of phonemes
1.	Nj	/ʈ/, /ɖ/, /ɭ/, /r/
2.	Ak	/ʈ/, /ɖ/, /ɳ/, /ɭ/
	Ny	/ɳ/
3.	Kj	/k/, /s/, /ʂ/, /r/
4.	An	/ʈ/, /ɖ/, /ɳ/, /ɭ/
5.	Sd	/ɭ/, /r/
6.	Sh	/ɳ/, /ɭ/
7.	Hd	/ɖ/, /ɭ/
8.	Fm	/s/, /r/
9.	Sj	/ʈ/, /ɖ/, /ɳ/, /ɭ/
10.	Ma	/s/, /ʂ/, /ʐ/, /ṛ/
11.	Es	/s/, /r/, /ṛ/
12.	Sc	/ʂ/, /ʐ/
13.	El	/ʐ/
14.	Dn	/ʐ/

3.2.3.4. Intervention procedure

A written consent was obtained from the parents/school authorities prior to the initiation of speech therapy and a sample of the same is provided in Appendix VIII. All ethical guidelines were followed during data collection (Basavaraj & Venkatesan, 2009). Articulation therapy was given in a quiet room in school or clinic to minimize distractions to the participants. The responses of the participants were audio recorded using Olympus multi track linear PCM recorder (Model: LS100) for perceptual analysis. The participants received a total of ten sessions of therapy for each phoneme which was determined based on the pilot study. Researcher provided two to three face-face individual therapy sessions in a week to the participants (Data collection was before the Covid 19 pandemic). Duration of each session was approximately 45 minutes. A total of 340 sessions of articulation therapy was provided to the 15 participants. Maximum of two target phonemes were considered for correction per session. The intervention for the target phoneme was carried out in the following steps.

Step 1: Three baselines were obtained using the assessment wordlist of target phoneme prior to the intervention procedure to ensure the consistency of articulatory errors. They were obtained with a gap of one week between each baseline. The third baseline which was obtained on the first intervention session served as the baseline of articulation for different vowel contexts and phoneme positions. Participants were instructed to repeat the word after the researcher and two opportunities were given for each word. Maximum score for each vowel context was ‘2’.

Step 2: Perceptual discrimination between error and target phoneme was evaluated using minimal pairs prior to the initiation of therapy. Perceptual training was carried out using minimal pairs in Malayalam (Rofina & Sreedevi, 2018), if the participant was unable to discriminate between the error and target phonemes.

Step 3: The articulatory intervention was carried out at word level using the intervention word list prepared. Picture and orthographic form of the target word was presented using Microsoft PowerPoint software (2017 version) on a 14-inch laptop screen (Dell inspiron 14R). Participants were instructed to repeat the target word after the researcher. No prompts or corrective feedback was given at this presentation.

On incorrect production of target phoneme, the correct production was taught at word level using an eclectic approach including phonetic placement (auditory, visual, tactile modalities or a combination of any). The aim of the study was to determine the facilitating vowel context and phoneme position for faster learning and not to establish the efficacy of the therapy technique used for articulation correction. Hence therapy technique was not considered as a variable in the study. Five opportunities were given to produce the phoneme correctly following which the researcher proceeded to the next word. On correct production of target phoneme, the researcher provided tactile or tangible reinforcement and moved on to the next word. Similarly, the entire wordlist was presented to the participant twice in a random order of words. First response of the two presentations i.e. the response without prompt or modelling was considered for analyses. Adequate breaks were given when the participants were distracted from the task.

Step 5: Mid therapy and post therapy assessments of participant's production of the target phoneme was obtained using the assessment wordlist on the fifth (mid therapy) and tenth sessions (post therapy). Assessment wordlist consisted of one word in each vowel context and phoneme position that are not part of the intervention wordlist. Participants were instructed to repeat the words after the clinician. Two opportunities were given for each word and both the responses were considered for analysis.

Step 6: The intervention was terminated after ten sessions for each phoneme to ensure equal number of sessions for all the participants. During intervention, parents were instructed not to train children on articulation at home. Further, parents were given home training programs after the termination of therapy for sustained correct production of phonemes. Wordlist for drilling and information on facilitating contexts observed during therapy was also provided for better hometraining.

3.2.3.5. Data Analyses

Recorded audio samples of assessment and intervention sessions were transferred to a laptop (Dell inspiron 14R) for analysis. The researcher analysed the audio samples of each participant using Praat software, Version 5.1.27 (Boersma & Weenink, 2010) by listening and transcribing their verbal responses using broad phonetic transcription (IPA, 2015). The transcribed samples were then scored for perceptually correct and incorrect productions. Correct production of only the target phoneme was considered and errors in other phonemes in the word were ignored. The correct productions were given a score of ‘1’ and incorrect productions were given a score of ‘0’.

To address the effect of vowel context and phoneme position independently and to check the interaction (combined effect of vowel context and phoneme position) between the two, scores of vowel contexts and phoneme positions were computed with respect to objectives. Ten phonemes (/ʈ, ɖ, ɳ, ɭ, ʂ, ʐ, s, r, ṛ, k/) were considered to study the effect of vowel context. Among the ten phonemes, seven phonemes were targeted in both initial and medial position of stimuli words. Here, scores of vowels in initial and medial positions were added to obtain a single score for each vowel context i.e., score of vowel /a/ in initial and medial positions were added to obtain a total score for /a/. Similarly, to study the effect of phoneme position on seven phonemes (/ʈ, ɖ, ʂ, s, r, ṛ, k), scores of all vowels in a phoneme position were added to obtain total score of that phoneme position. For example, if initial position had words in five vowel contexts, scores of the five vowels were added to obtain a total score for initial position. To study the combined effect of vowel context and phoneme position, scores of vowels were analysed separately for initial and medial positions. Percentage of correct production was computed from the raw scores calculated using the following formula.

$$\text{Percentage of correct production} = \frac{No.of\ correct\ productions}{Total\ no.\ of\ opportunities\ given}$$

3.2.3.6. Statistical analyses

Statistical analyses were carried out using SPSS (Statistical Package for Social Science) version 21. Independent variables considered in the study were vowel contexts and phoneme positions and the dependent variable was percentage of correct production scores. The technique used for articulatory correction (phonetic placement) was not a variable as the aim of the study was to identify the facilitating vowel context and phoneme position in which a phoneme was learnt faster and not to establish efficacy of the technique. Descriptive statistics and inferential statistics were run for phonemes with minimum of three participants.

Descriptive statistical analysis was carried out to obtain mean, standard deviation, median and interquartile range of percentage of correct production scores of first (pre-therapy) and tenth sessions (post-therapy). Non parametric tests were employed for inferential statistical analyses as the sample size was small ('n' ranged from 3-5). Wilcoxon signed rank test was run for pre-post therapy comparison.

Inter judge and intra judge reliability was computed using Cronbach's alpha. For inter judge reliability three speech language pathologists who were native speakers of Malayalam with minimum 3 years of clinical or research experience in perceptual analysis of speech were selected. Among the three judges, investigator also served as one of the judges. 50% samples of all participants were reanalysed by three judges. For intra judge reliability, researcher reanalysed 50% samples of all participants with a gap of minimum one month after the initial analysis.

3.2.3.7. Visual analysis

Kratochwill et al. (2010) recommended that it is necessary to make a visual analysis of both within- and between phase data to assess the effects of interventions in single subject studies. In this view, percentage of correct production in each context was calculated, tabulated, and graphically represented using Microsoft Office Excel (2007). Scores were represented on a line diagram as shown in Figure 3.1. A phoneme was considered to be learnt when the participant produced it correctly for 80% of the time (Sanders, 1972). Three measures were computed for each vowel context and phoneme position and based on them three criteria were set to decide the most facilitating context. The parameters and criteria are listed below.

1. **Minimum number of sessions for consistent correct production (MNS-CCP):** it is the minimum number of sessions needed to maintain 80% accuracy for three consecutive sessions in a particular vowel context. This was computed for all vowel contexts and phoneme positions for a target phoneme. Vowel context and phoneme position in which the participant required minimum sessions to learn the correct production of target phoneme was considered as the most facilitating context i. e. the vowel context with least MNS-CCP

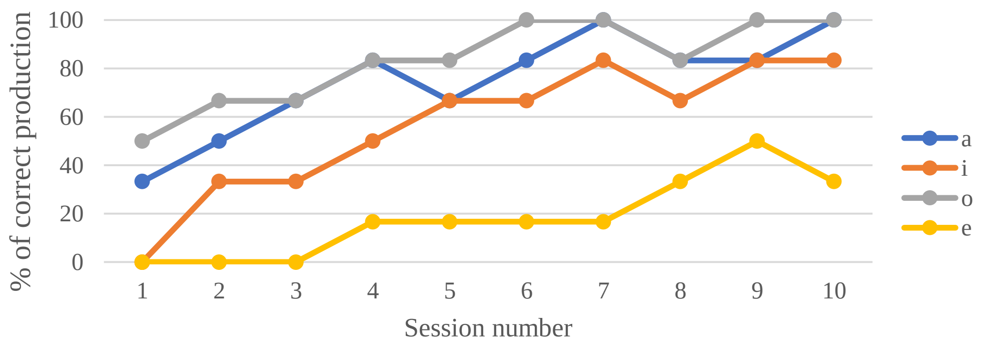
2. **Total number of sessions with correct production (TNS-CP):** In the absence of consistent correct production in three consecutive sessions, vowel context in which the participant could achieve 80% correct production of target phoneme for total number of sessions with correct production (TNS-CP) was considered as facilitating context. That is, TNS-CP is the number of sessions in which the participant could produce the phoneme correctly for

80% of the time in a particular vowel context out of the ten sessions of articulation therapy. For e.g. if a participant could produce the phoneme /k/ correctly in seven out of ten sessions of therapy in the context of /a/, then TNS-CP for /a/ is seven.

3. **Minimum Number of Sessions for Correct Production (MNS-CP)**: it is the minimum number of sessions within which the participant could produce the phoneme correctly for 80% of the time. Consistency of correct production is not considered to compute this parameter. If there were two contexts which were comparable in any of the above criterion, then the context in which the 80% correct production of phoneme first met was considered as the facilitating context i.e. vowel context with least MNS-CP.

Figure 3.1.

Example of graphical representation of data for unvoiced retroflex /ʈ/ in word initial position for participant Sj



In figure 3.1, the session numbers are shown in the X axis and the percentage of correct production of the phoneme is shown on the Y axis. The performance of the participant across different vowel contexts is represented in the graph using solid lines of various colours. MNS-CP, MNS-CCP and TNS-CP were computed from the figure and are tabulated in table 3.6.

Table 3.6.

Sample table to determine facilitating vowel context for unvoiced retroflex stop /ʈ/ in initial position for participant Sj

Participant	**Initial**			
Sj	**/a/**	**/i/**	**/e/**	**/o/**
MNS-CP	4	7	**-**	**4**
MNS-CCP	6	-	**-**	**4**
TNS-CP	6	3	**-**	**7**

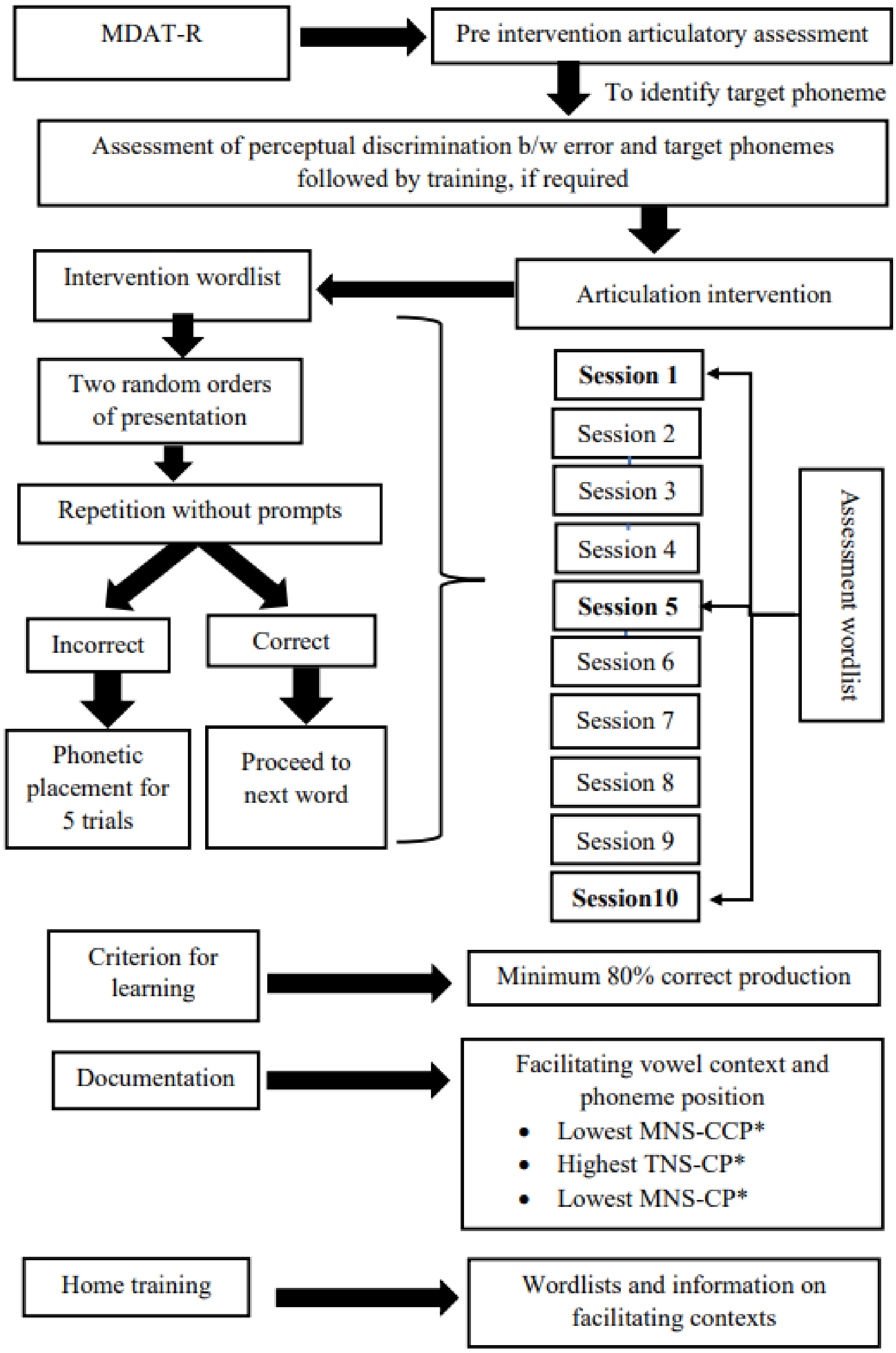
Note. MNS-CP = minimum number of sessions with correct production, MNS-CCP=minimum number of sessions for consistent correct production, TNS-CP= maximum number of sessions with correct production. Facilitating vowel contexts are marked as bold.

It could be observed that in the context of /o/, the participant could produce /ʈ/ correctly for 80% of the time from 4th session onwards and it was maintained for 7 consecutive sessions i.e. MNS-CCP is 4 and TNS-CP is 7. In the context of vowel /a/, the criterion was met by sixth session. Since /o/ was the vowel context in which the target phoneme was learnt faster, it is considered as the most facilitating vowel context in initial position for unvoiced retroflex stop /ʈ/ (e.g. /**ʈo:**m/). Similarly, the responses of the participants were analysed in the initial and medial positions for all the phonemes considered in the study

Figure 3.2 shows a flowchart representation of the intervention procedure.

Figure 3.2

Flowchart of intervention procedure.



Note. MNS-CCP = minimum number of sessions required for consistent correct production, TNS-CP = total number of sessions with correct production, MNS-CP = minimum number of sessions required for correct production.

3.2.4. Phase 4 - Validation of the results

Validation was not part of the research proposal. However, it was carried out based on availability of participants. Results obtained in phase 3 of the study was validated on three Malayalam speaking children with DS. The inclusion criteria followed was similar to that of phase 3. Assessment and intervention of the participants were carried out by a SLP, who was not part of Phase 3. Demographic details and articulatory profile of the participants are shown in table 3.7

Table 3.7

Demographic details and articulatory profile of participants for validation of results

Participants		Dy	Gd	Js
Age		8:5 years	9:3 years	10:1 years
Gender		Female	Male	Male
IQ		55	60	49
Severity of ID		Mild	Mild	Moderate
Articulatory errors (No. of errors)		n/ɳ, l/ɭ, d/r, t/ʈ, n/r, j/ṛ, d/ɖ, j/r, j/ʐ (9)	l/ɭ, j/ṛ, j/r, j/ʐ, s/ʃ (5)	n/ɳ, d/r, t/ʈ, n/r, j/ṛ, d/ɖ, j/r, j/ʐ (5)
Consistency of errors		Consistent	Consistent	Consistent
Intelligibility		3-somewhat intelligible in conversation	2-mostly intelligible in conversation	2-mostly intelligible in conversation
Discrimination	**Inter personal**	Fair	Good	Fair
	Intra personal	Fair	Good	Fair
Severity (PCC-R)		Moderate (52.45%)	Moderate (63.64%)	Moderate (62.45%)
Target phoneme		/ɳ/, /ɭ/	/ɭ/	/ɳ/

Note. IQ=intelligence quotient, ID=intellectual disability, PCC-R=percentage of consonants correct-revised.

Based on the articulatory errors of the participants the following phonemes were selected for intervention: **/ɳ/** and **/ɭ/** for **Dy, /ɭ/** for **Gd** and **/ɳ/** for **Js.** The intervention procedure followed was similar to phase 3 of the study. Intervention was provided only in the facilitating contexts of the respective phonemes identified in phase 3 and percentage of correct production was documented for each session. The number of sessions required to achieve 80% correct production was documented for the three participants recruited for validation and was compared with the average number of sessions required to achieve the same criterion for the participants of phase 3 of the study. If significant change towards correct production of the target consonant was observed within the stipulated number of sessions, the findings on facilitating vowel contexts and phoneme positions from the main study is credited as valid.

Chapter 4: Results

The present study aimed at investigating the effect of vowel contexts and phoneme positions on facilitating the correct production of frequently misarticulated phonemes in Malayalam speaking children with Down syndrome by providing articulation therapy.

The objectives formulated were

1. To study the effect of vowel contexts (/a/, /i/, /u/, /e/ and /o/) on the correct production of ten frequently misarticulated phonemes (/ʈ, ɖ, ɳ, ɭ, k, s, ʂ, r, ṛ, ʐ/) in Malayalam speaking children with Down syndrome.
2. To determine the rank order of vowel contexts facilitating the correct production of ten frequently misarticulated phonemes (/ʈ, ɖ, ɳ, ɭ, k, s, ʂ, r, ṛ, ʐ/) in Malayalam speaking children with Down syndrome.
3. To study the effect of phoneme position (initial or medial) on the correct production of seven frequently misarticulated phonemes (/ʈ, ɖ, k, s, ʂ, r, ṛ/) in Malayalam speaking children with Down syndrome.
4. To determine the rank order of phoneme positions facilitating the correct production of seven frequently misarticulated phonemes (/ʈ, ɖ, k, s, ʂ, r, ṛ/) in Malayalam speaking children with Down syndrome.
5. To study the interaction of vowel contexts and phoneme position on production of seven frequently misarticulated phonemes in Malayalam speaking children with Down syndrome.

Among the 10 phonemes considered in the present study, only seven phonemes occur in both initial and medial positions in Malayalam. Hence in the third, fourth and fifth objectives to check the effect of phoneme position (initial and medial) and to study the interaction of vowel context and phoneme position (combined effect of vowel context and phoneme position), only these seven phonemes were considered.

The study was conducted in four phases.

Phase I: Preparation of assessment and intervention wordlists for ten commonly misarticulated phonemes in Malayalam. This included words with target phonemes occurring in the context of various vowels in initial and medial positions as per the phonotactic rules of Malayalam.

Phase II: Pilot study was conducted on three Malayalam speaking children with DS to determine the number of sessions required to achieve 80% correct production in at least one vowel context and number of rounds of presentation of wordlist. Based on the pilot study ten sessions were fixed for each target phoneme and two random orders of presentation of wordlist was found to be feasible.

Phase III: Establishment of facilitating vowel contexts and phoneme positions for frequently misarticulated phonemes by providing articulation therapy.

Phase IV: Validation of results obtained in phase III on three Malayalam speaking children with DS.

Results of phase III and phase IV will be discussed in detail in the upcoming sections.

In Phase III of the study, a total of 15 Malayalam speaking children with Down syndrome (7 males & 8 females) served as participants. Articulation abilities of these children were assessed using Malayalam Diagnostic Articulation Test – Revised (Neenu et al., 2011) and ten phonemes were selected for articulatory intervention based on the articulatory errors of the participants. This included six retroflex phonemes: stops **/ʈ/** and **/ɖ/,** nasal **/ɳ/**, lateral **/ɭ/,** fricative **/ʂ/** and approximant **/ɻ/,** three alveolar phonemes including fricative **/s/**, tap **/r/,** trill **/r̩/** and one velar phoneme **/k/**.

Assessment and intervention wordlists prepared during Phase I served as stimuli for this phase. Assessment wordlist was used to check the learning during first, fifth and tenth intervention sessions. Intervention wordlist was used as stimuli for articulation therapy. Participants received a total of 10 sessions of intervention for each phoneme with a frequency of two to three sessions per week which was determined based on the pilot study. The participants received a total of 340 sessions of articulation therapy. Verbal imitation task was employed for elicitation of the target word. On incorrect production, Phonetic placement approach (Van Riper, 1972) was used to teach the correct production of target phoneme. Percentage of correct production of the target phoneme was calculated for each vowel context and phoneme position across ten sessions. To consider a phoneme as learnt in a context, a minimum of 80% correct production of the phoneme was set as the criterion.

Statistical analysis of data was conducted for phonemes with minimum of three participants for speech therapy and this included unvoiced retroflex stop **/ʈ/**, voiced retroflex stop **/ɖ/,** retroflex fricative **/ʂ/,** retroflex nasal **/ɳ/,** retroflex lateral **/ɭ/** and alveolar fricative **/s/.** Descriptive analysis of data was carried out to obtain mean, median, standard deviation and interquartile range. As the sample size was small (n ranged from 3-5) and standard deviation of data was high for certain vowel contexts and phoneme positions, non-parametric tests were employed for inferential statistics. Wilcoxon signed rank test was run for pre-post therapy comparison. On analysing the descriptive statistical measures (mean & median), pre therapy scores were less than 25% and post-therapy scores were greater than 90% for most of the phonemes indicating a reasonably large difference. However, Wilcoxon signed rank test did not show significance on pre-post therapy comparison ($1.60 < |z| < 1.83$, $p>0.05$). This contradiction in finding could be due to limited sample size (n ranged from 3-5). Hence, group analysis did not serve the purpose of the study, i.e. to establish the most facilitating context for the correct production of the target phoneme. Hence the data was analysed qualitatively.

Qualitative analysis of the data was carried out by visual analysis of line diagrams. Here responses of the participants for each phoneme across ten sessions were represented using line diagrams and facilitating vowel context was determined based on the following three measures computed from the line diagrams.

- Minimum Number of Sessions for Correct Production (MNS-CP): It is the minimum number of sessions required to achieve 80% correct production of the target phoneme in a particular context.
- Minimum Number of Sessions for Consistent Correct Production (MNS-CCP): It is the minimum number of sessions required to achieve 80% correct production for three consecutive sessions in a particular vowel context. Vowel context with lowest MNS-CCP is considered as the most facilitating context.
- Total Number of Sessions with Correct Production (TNS-CP): It is the total number of sessions in which the participant could achieve 80% correct production in a context out of 10 sessions of therapy.

Based on the objectives of the study, results will be discussed under the following sections

1. Effect of vowel context on correct production of target phonemes in children with DS

2. Effect of target phoneme position on correct production of phonemes in children with DS
3. Interaction of vowel context and phoneme position
4. Validation of findings on three additional participants with DS

4.1. Effect of vowel context on production of phonemes in children with DS

Results of the first two objectives of the study will be discussed in this section i.e. the effect of vowel context on correct production of phonemes and the rank order of vowel contexts. Ten phonemes were considered under this objective. Percentage of correct production for each vowel context was calculated for ten sessions for each participant for the respective error phonemes. Among the ten phonemes considered for intervention, seven phonemes (/ʈ, ɖ, r, ṛ, s, ʂ, k) had target words in both initial and medial positions and the remaining three phonemes (/ɳ, ɭ, ɻ/) had target words only in medial position as per the phonotactics of Malayalam. For seven phonemes with target words in both initial and medial positions, raw scores in both positions (initial & medial) of each vowel context was combined to obtain a single score for that vowel context and percentage of correct production was calculated. Results will be discussed under the respective phonemes.

4.1.1. Unvoiced retroflex stop /ʈ/.

The unvoiced retroflex stop **/ʈ/** is mastered by the age of 3-3.3 years in Malayalam (Neenu et al., 2011). The articulation of **/ʈ/** was worked upon in four participants in the present study i.e. **Sj (**10.5 years /male), **Nj** (8.3 years/Male), **Ak** (8.1 years/Male) and **An** (10.3 years/Male). All participants substituted unvoiced dental stop /t/ for unvoiced retroflex stop **/ʈ/**.

In the present study production of **/ʈ/** was studied in the context of five vowels /a/, /i/, /u/, /o/ and /e/. Target words were considered in both initial and medial positions. As mentioned earlier, scores of each of the vowel context in initial and medial position were combined to obtain a single score and percentage of correct production was calculated. Mean, standard deviation, median and inter quartile range of first (pre-therapy) and tenth sessions (post-therapy) are tabulated in Table 4.1

Table 4.1.

Mean, standard deviation, median and inter quartile range of 1st and 10th sessions for /ʈ/ in five vowel contexts.

Vowel context	Score	Mean	SD	Median	IQR
/a/	**Pre-TS**	25.00	11.79	20.83	20.84
	Post-TS	95.83	4.81	95.83	8.33
/i/	**Pre-TS**	10.41	4.17	8.33	6.25
	Post-TS	85.41	10.49	83.33	18.75
/u/	**Pre-TS**	25.00	31.91	16.67	58.33
	Post-TS	91.67	9.62	91.67	16.67
/o/	**Pre-TS**	24.92	21.47	24.83	41.58
	Post-TS	100.00	0.00	100.00	0.00
/e/	**Pre-TS**	0.00	0.00	0.00	0.00
	Post-TS	58.33	28.87	50.00	50.00

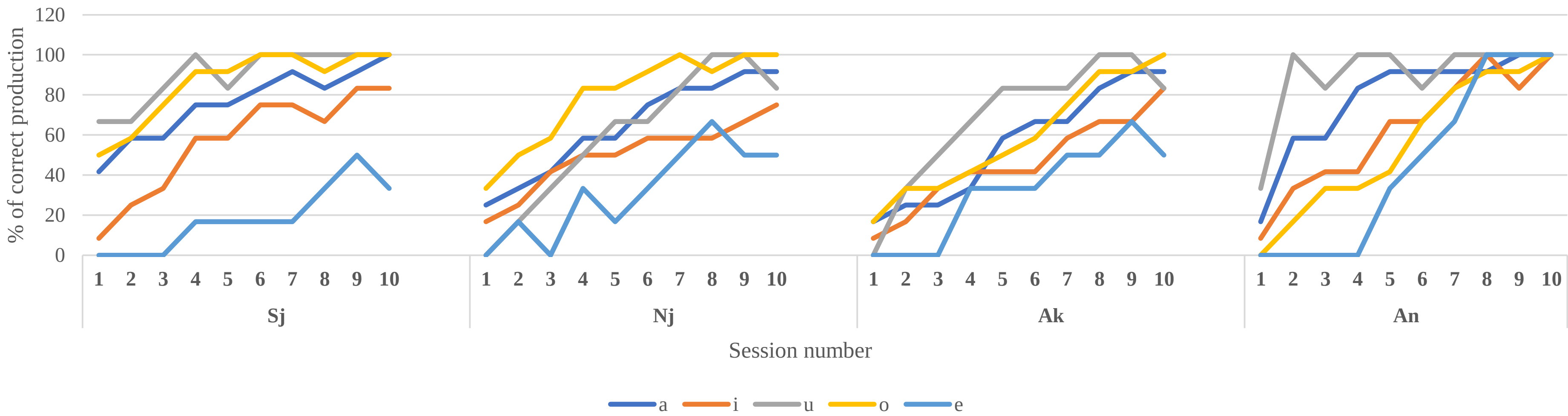
Note. SD=standard deviation, IQR=inter quartile range, Pre-TS=Pre therapy score, Post-TS=Post therapy score.

From Table 4.1, it could be observed that percentage of correct production scores increased from pre-therapy to post-therapy in all the vowel contexts. In most of the contexts except in context of vowels /i/ and /e/, post-therapy scores were above 90%. Variability of production in terms of standard deviation and interquartile range was high during pre-therapy but it reduced towards post-therapy in the context of /a/, /u/ and /o/ whereas, the variability increased in the context of /i/ and /e/.

For visual analysis of data, responses of participants across ten sessions in various vowel contexts are represented in a line diagram as shown in Figure 4.1

Figure 4.1

Percentage of correct production of /ʈ/ across ten sessions for participants ***Sj, Nj, Ak*** *and* ***An*** *in five vowel contexts.*



From Figure 4.1, it could be noted that vowel /u/ context led to better production of **/ʈ/** in all the participants except **Nj** who performed better in the context of /o/. Overall, the performance of participants showed improvement in all vowel contexts as the sessions progressed. All participants had least percentage of correct production in the context of vowel /e/.

To determine the facilitating vowel contexts, minimum number of sessions for correct production (MNS-CP), minimum number of sessions for consistent correct production (MNS-CCP) and total number of sessions with correct production (TNS-CP) were computed from the graph and are tabulated in Table 4.2.

Table 4.2.

MNS-CP, MNS-CCP and TNS-CP values of four participants for phoneme /ʈ/ in five vowel contexts

Participant	Parameter	/a/	/i/	/u/	/o/	/e/
Sj	**MNS-CP**	6	9	**3**	4	-
	MNS-CCP	6	-	**3**	4	-
	TNS-CP	5	2	**8**	7	-
Nj	**MNS-CP**	7	-	7	**4**	-
	MNS-CCP	7	-	7	**4**	-
	TNS-CP	4	-	4	**7**	-
Ak	**MNS-CP**	8	10	**5**	8	-
	MNS-CCP	8	-	**5**	8	-
	TNS-CP	3	1	**6**	3	-
An	**MNS-CP**	4	7	**2**	7	8
	MNS-CCP	4	7	**2**	7	8
	TNS-CP	7	4	**9**	4	3

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

From Table 4.2, it could be observed that in the context of high back vowel **/u/,** three of the participants (**Sj, Ak & An**) required minimum number of sessions to achieve the target percentage of correct production (80%). The number of sessions for consistent production in three consecutive sessions ranged from two to five (MNS-CCP=3-5). One participant (**Nj**) learnt the phoneme faster in the context of mid back vowel /o/ and he required four sessions to achieve the target criterion (MNS-CCP=4).

To determine the order of facilitating vowel contexts an attempt was made to arrange the vowel contexts in the increasing order of number of sessions for consistent correct production (MNS-CCP). However, a common trend could not be identified across participants. One interesting observation was that mid front vowel /e/ resulted in poorer scores in all the four participants. Hence /e/ is the least facilitating context for unvoiced retroflex stop **/ʈ/.** To conclude, the production of unvoiced retroflex stop **/ʈ/** was facilitated in the context of **high back vowel /u/** (e.g. /ca***ʈʈu***gam/) in the participants of present study.

4.1.2. Voiced retroflex stop /ɖ/.

The voiced retroflex stop **/ɖ/** is mastered by the age of 3- 3.3 years in Malayalam (Neenu et al., 2011). The articulation of **/ɖ/** was worked upon in five participants in the present study i.e., **Sj** (10.5 years /male), **Nj** (8.3 years/Male), **An** (10.3 years/Male), **Hd** (10.10 years/Female) and **Ak** (8.1 years/Male). All the participants substituted voiced dental stop /d/ for **/ɖ/**. Among the five participants, participant **Ak** could not meet the targeted level of correct production consistently. Hence results of this participant is not discussed in this section.

Production of **/ɖ/** was studied in the context of five vowels /a/, /i/, /u/, /o/ and /e/. As there were target words in both initial and medial positions, scores of respective vowels in both positions were combined. Mean, standard deviation, median and inter quartile range of first (pre-therapy) and tenth sessions (post-therapy) are tabulated in Table 4.3.

Table 4.3.

Mean, standard deviation, median and inter quartile range of 1st and 10th sessions for /ɖ/ in five vowel contexts.

Vowel context	Score	Mean	SD	Median	IQR
/a/	**Pre-TS**	25.00	11.79	20.83	20.84
	Post-TS	95.83	4.81	95.83	8.33
/i/	**Pre-TS**	10.41	4.17	8.33	6.25
	Post-TS	85.41	10.49	83.33	18.75
/u/	**Pre-TS**	25.00	31.91	16.67	58.33
	Post-TS	91.67	9.62	91.67	16.67
/o/	**Pre-TS**	25.00	21.47	24.83	41.58
	Post-TS	100.00	0.00	100.00	0.00
/e/	**Pre-TS**	0.00	0.00	0.00	0.00
	Post-TS	58.33	28.87	50.00	50.00

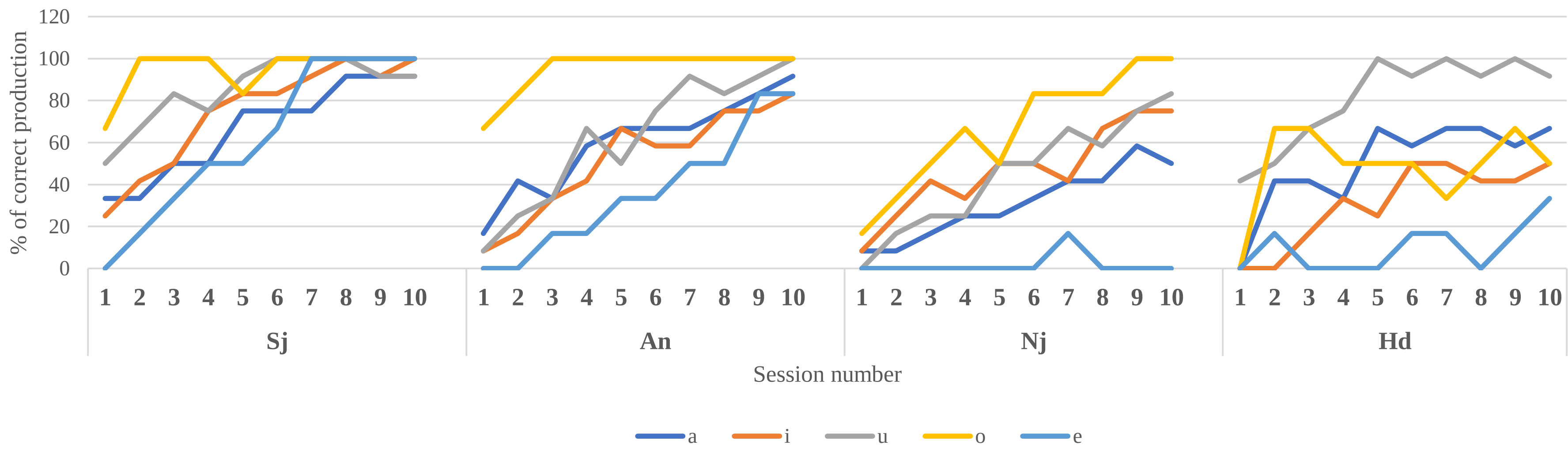
Note. SD=standard deviation, IQR=inter quartile range, Pre-TS=Pre therapy score, Post-TS=Post therapy score.

On analyzing the pre-therapy scores across vowel contexts, it could be noted that the median scores of the participants ranged from 0 to 24.83%, where lowest score was documented in context of /e/. Comparison of post-therapy scores across vowel contexts revealed that median scores were highest in the context of vowel /o/ (100%) and lowest in the context of vowel /e/ (50%). Standard deviation and interquartile range values were high for certain vowel contexts indicating high variability of data.

For qualitative analysis of data, responses of the participants in five vowel contexts across ten sessions of therapy were represented in a line diagram as shown in Figure 4.2.

Figure 4.2.

*Percentage of correct production of /ɖ/ across ten sessions for participants **Sj, An, Nj** and **Hd** in five vowel contexts.*



As observed from the Figure 4.2, overall, percentage of correct production increased from baseline scores in most of the vowel contexts. Three out of four participants (**Sj, An** & **Nj**) learnt to produce **/ɖ/** faster in the context of vowel **/o/** whereas one participant (**Hd**) learnt **/ɖ/** in the context of vowel **/u/.** Similar to unvoiced retroflex stop **/ʈ/,** all the participants demonstrated poorer performance in the context of vowel /e/. For participant **Nj** and **Hd**, post-therapy scores of /e/ did not improve markedly even after ten sessions of therapy.

To determine the facilitating vowel contexts, minimum number of sessions for correct production (MNS-CP), minimum number of sessions for consistent correct production (MNS-CCP) and total number of sessions with correct production (TNS-CP) were computed from the graph and tabulated in Table 4.4.

Table 4.4.

MNS-CP, MNS-CCP and TNS-CP values of four participants for /ɖ/ in five vowel contexts

Participant	Parameter	/a/	/i/	/u/	/o/	/e/
Sj	**MNS-CP**	8	5	3	**2**	7
	MNS-CCP	8	5	5	**2**	7
	TNS-CP	3	6	7	**9**	4
An	**MNS-CP**	9	10	7	**2**	9
	MNS-CCP	-	-	7	**2**	-
	TNS-CP	2	1	4	**9**	2
Nj	**MNS-CP**	-	-	10	**6**	-
	MNS-CCP	-	-	-	**6**	-
	TNS-CP	-	-	1	**5**	
Hd	**MNS-CP**	-	-	**5**	-	-
	MNS-CCP	-	-	**5**	-	-
	TNS-CP	-	-	**6**	-	-

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

On comparing the number of sessions required to learn the production of **/ɖ/** across vowel contexts, three participants (**Sj, An & Nj**) required minimum number of sessions in the context of vowel **/o/.** The number of sessions required for consistent correct production ranged from two to six for vowel **/o/** (MNS-CCP=2-6). One participant (**Hd**) showed faster learning of **/ɖ/** in the context of vowel **/u/** and she required five sessions to meet the target criterion of 80% correct production (MNS-CCP=5).

As attempted for unvoiced retroflex stop **/ʈ/,** vowels were arranged in increasing order of MNS-CCP to identify the rank order of facilitating vowel contexts. A consistent facilitatory effect of mid back vowel /o/ followed by high back vowel /u/ was observed in three participants. A common trend could not be identified for remaining vowels. To conclude, **mid back vowel /o/** (/***ɖo:***ɭ) followed by **high back vowel /u/** (e.g. /***ɖu:***ɖu/) facilitated the production of **voiced retroflex stop /ɖ/** in the present study.

4.1.3. Retroflex nasal /ɳ/.

The retroflex nasal **/ɳ/** is mastered by the age of 4.1 - 4.3 years in Malayalam (Neenu et al., 2011). The articulation of **/ɳ/** was worked upon in five participants in the present study i.e. **Sj** (10.5 years /male), **An** (10.3 years/Male), **Ak** (8.1 years/Male), **Sh** (9:1 years/Male) and **Ny** (10:3 years/Female). Participants **Sj, Ak** and **Sh** substituted **/ɳ/** with alveolar nasal **/n/** and participants **An** and **Ny** with dental nasal /n̪/.

In the present study, production of **/ɳ/** was investigated only in medial position in the contexts of vowels /a/, /i/ and /u/ as phonotactics of Malayalam does not permit the occurrence of /**ɳ/** in initial position. Mean, standard deviation, median and inter quartile range scores of first (pre-therapy) and tenth sessions (post-therapy) are tabulated in Table 4.5.

Table 4.5.

Mean, standard deviation, median and inter quartile range of 1st and 10th sessions for /ɳ / in three vowel contexts.

Vowel context	Score	Mean	SD	Median	IQR
/a/	**Pre-TS**	16.66	20.41	16.66	33.33
	Post-TS	90.00	14.91	100.00	25.00
/i/	**Pre-TS**	0.00	0.00	0.00	0.00
	Post-TS	56.67	25.28	50.00	33.33
/u/	**Pre-TS**	23.32	27.86	16.66	49.97
	Post-TS	93.33	9.13	100.00	16.67

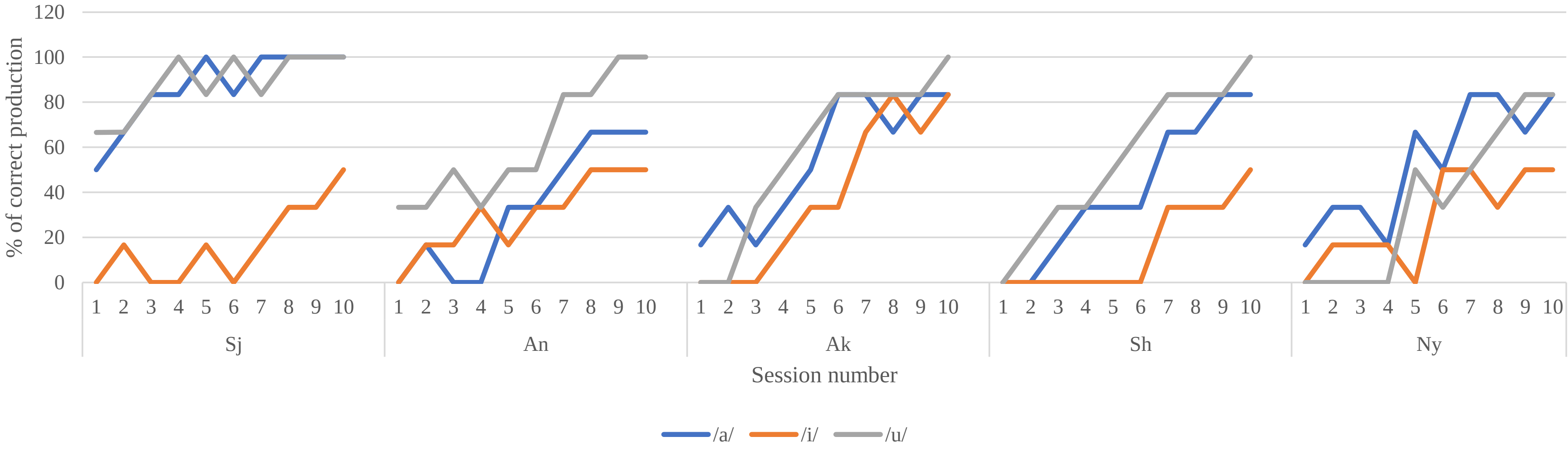
Note. SD=standard deviation, IQR=inter quartile range, Pre-TS=Pre therapy score, Post-TS=Post therapy score.

On comparing the median pre-therapy and post-therapy scores, vowel /i/ had the least score and vowel /u/ had the highest. Pre-therapy scores were 0% in the context of /u/, 16.66% in the context of /a/ and /u/. Median post-therapy scores increased to 100% in the context of /a/ and /u/, whereas, it was only 50% in the context of /i/.

For qualitative analysis, performance of participants **Sj, An, Ak, Sh** and **Ny** across ten sessions of therapy are represented in a line diagram as shown in Figure 4.3.

Figure 4.3.

*Percentage of correct production of /ɳ/ across ten sessions for participants **Sj, An, Ak, Sh** and **Ny** in three vowel contexts*



On observing the trend in Figure 4.3, two participants (**An & Sh**) had distinctly better production of **/ɳ/** in the context of vowel /u/ whereas, for two participants (**Sj & Ak**), performance in the context of vowel /u/ and /a/ were comparable. Vowel /a/ was advantageous for one participant (**Ny**). All the participants had the lowest percentage of correct production in the context of /i/. The overall trend of the graph revealed a marked increase in correct production of **/ɳ/** in all vowel contexts as the sessions progressed.

To determine the facilitating vowel context for **/ɳ/,** minimum number of sessions for correct production (MNS-CP), minimum number of sessions for consistent correct production (MNS-CCP) and total number of sessions with correct production (TNS-CP) were computed from the graphs and tabulated in Table 4.6.

Table 4.6

MNS-CP, MNS-CCP and TNS-CP values of five participants for /ɳ/ in three vowel contexts

Participant	Parameter	/a/	/i/	/u/
Sj	**MNS-CP**	**3**	-	**3**
	MNS-CCP	**3**	-	**3**
	TNS-CP	**8**	-	**8**
An	**MNS-CP**	-	-	**7**
	MNS-CCP	-	-	**7**
	TNS-CP	-	-	**4**
Ak	**MNS-CP**	6	8	**6**
	MNS-CCP	-	-	**6**
	TNS-CP	4	2	**5**
Sh	**MNS-CP**	9	-	**7**
	MNS-CCP	-	-	**7**
	TNS-CP	2	-	**4**
Ny	**MNS-CP**	**7**	-	9
	MNS-CCP	**-**	-	-
	TNS-CP	**3**	-	2

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

From Table 4.6, it could be observed that four (**Sj, An, Ak** & **Sh**) out of five participants learnt to produce **/ɳ/** correctly in the context of /u/ within 3-7 sessions

(MNS-CCP= 3-7). Apart from /u/, **Sj** achieved 80% correct production in the context of **/a/** also by session three itself (MNS-CCP=3). Participant **Ny** learnt **/ɳ/** in the context of **/a/** by seven sessions (MNS-CP=7). However, the production was inconsistent.

To address the second objective of the study to determine rank order of facilitating vowel contexts, vowels were arranged in ascending order of MNS-CCP. For most of the participants the most facilitating context was /u/ followed by /a/ and then by /i/ i.e. /u/ > /a/ > /i/. To conclude, production of **retroflex nasal /ɳ/** was facilitated in the context of **high back vowel /u/** (e.g. /ta***ɳu***ppə/) followed by **low central vowel /a/** (e.g./e***ɳɳa***/) followed by **high front vowel /i/** (e.g. /to:***ɳi***/) in the present study.

4.1.4. Retroflex lateral /ɭ/.

The retroflex lateral **/ɭ/** was mastered by the age of 4.1-4.3 years in Malayalam (Neenu et al., 2011). The articulation of **/ɭ/** was worked upon in seven participants in the present study i.e. **Sj** (10.5 years /Male), **Ak** (8.1 years/Male), **Nj** (8:3 years/Male), **Sd** (8 years/Male), **Hd** (10:10 years/Female), An (10.3 years/Male) and **Sh** (9.1 years/Male). All the participants substituted alveolar lateral /l/ for **/ɭ/**. Two participants (**An** & **Sh)** could not achieve the target criterion within ten sessions; hence their results will not be discussed in this section.

In the present study, production of **/ɭ/** was investigated only in the contexts of three vowels /a/, /i/ and /u/. Mean, standard deviation, median and inter quartile range of first (pre-therapy) and tenth sessions (post-therapy) are tabulated in Table 4.7.

Table 4.7.

Mean, standard deviation, median and inter quartile range of 1^{st} and 10^{th} sessions for /ɭ/ in three vowel contexts.

Vowel context	Score	Mean	SD	Median	IQR
/a/	**Pre-TS**	30.00	18.26	33.33	25.00
	Post-TS	93.33	9.13	100.00	16.67
/i/	**Pre-TS**	6.66	9.13	0.00	16.66
	Post-TS	70.00	27.39	83.33	50.00
/u/	**Pre-TS**	43.33	9.13	50.00	16.67
	Post-TS	96.67	7.46	100.00	8.33

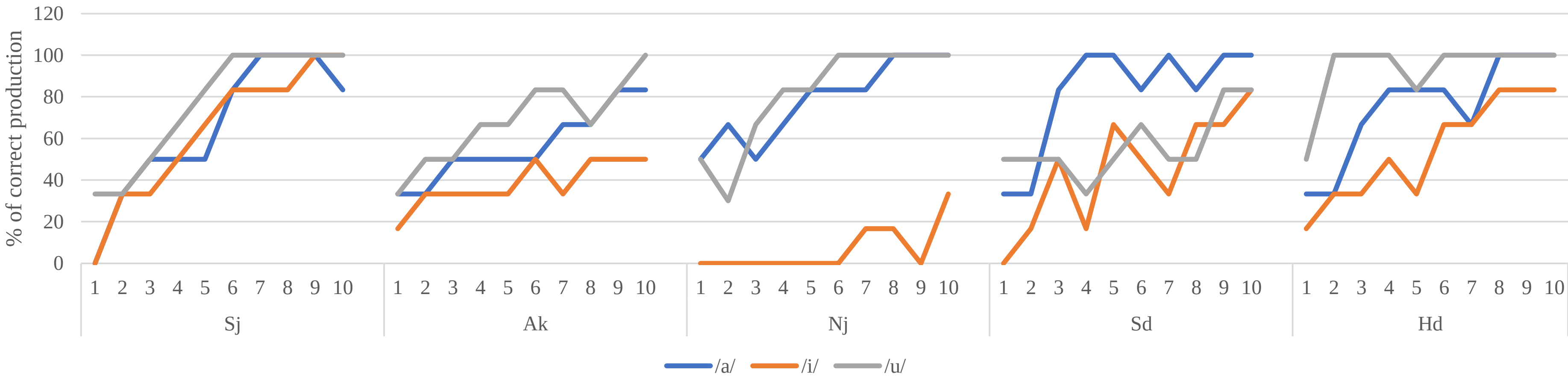
Note. SD=standard deviation, IQR=inter quartile range, Pre-TS=Pre therapy score, Post-TS=Post therapy score.

As evident from Table 4.7, percentage of correct production scores increased from pre-therapy to post therapy in all vowel contexts. Median post-therapy scores of vowel /a/and /u/ increased up to 100% indicating good progress. However, it was only 83.33% in the context of /i/. Standard deviation values were less in all the vowel context except vowel /i/ during post therapy.

For qualitative analysis, performance of participants across ten sessions of therapy in three vowel contexts were represented in a line diagram as shown in Figure 4.4.

Figure 4.4.

*Percentage of correct production of /ɭ/ across ten sessions for participants **Sj, Ak, Nj, Sd** and **Hd** in three vowel contexts*



On analysing the performance of participants in different vowel contexts, it was evident that context of vowel **/u/** resulted in better production of **/ɭ/** in four out of five participants (**Sj, Ak, Nj** & **Hd**) and vowel /a/ in one participant (**Sd**). Participants' percentage of correct production scores increased as the sessions progressed and the performance was relatively consistent for all participants except participant **Sd.** Vowel /i/ context resulted in poorer scores in all the participants.

To determine the facilitating vowel context for /**ɭ**/, minimum number of sessions for correct production (MNS-CP), minimum number of sessions for consistent correct production (MNS-CCP) and total number of sessions with correct production (TNS-CP) were computed from the graphs and tabulated in Table 4.8.

Table 4.8

MNS-CP, MNS-CCP and TNS-CP values of five participants for /ɭ/ in three vowel contexts

Participant	**Parameter**	**/a/**	**/i/**	**/u/**
Sj	**MNS-CP**	6	6	**5**
	MNS-CCP	6	6	**5**
	TNS-CP	5	5	**6**
Ak	**MNS-CP**	9	-	**6**
	MNS-CCP	-	-	**-**
	TNS-CP	2	-	**4**
Nj	**MNS-CP**	5	-	**4**
	MNS-CCP	5	-	**4**
	TNS-CP	6	-	**7**
Sd	**MNS-CP**	**3**	10	9
	MNS-CCP	**3**	-	-
	TNS-CP	**8**	1	2
Hd	**MNS-CP**	4	8	**2**
	MNS-CCP	4	8	**2**
	TNS-CP	6	3	**9**

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

Similar to the observations from Figure 4.4, four participants (**Sj, Ak, Nj** & **Sd**) required fewer sessions to learn the correct production of /**ɭ**/ in the context of /u/

(MNS-CCP=2-5). Among these four participants, **Ak** could not maintain the targeted percentage of correct production for three consecutive sessions. However, he could produce **/ɭ/** with 80% accuracy for four non-consecutive sessions (TNS-CP=4). Vowel /a/ resulted in faster learning in one participant (**Hd**). Minimum number of sessions for consistent correct production was three sessions for vowel /a/ (MNS-CCP=3).

The vowels were also arranged in the increasing order of MNS-CCP to determine the rank order of vowel contexts. In most of the participants the order was as follows: /u/ < /a/ < /i/. in other words, participants required least number of sessions to learn the correct production of **/ɭ/** in the context of /u/ followed by /a/ followed by /i/. To conclude, **high back vowel /u/** (e.g. /ve***ɭu***ppə) followed by **low central vowel /a/** (e.g. /ka:***ɭa***/) followed by **high front vowel /i/** (e.g. /u***ɭɭi***/) facilitated the correct production of **/ɭ/** for participants of the present study.

4.1.5. Unvoiced retroflex fricative /ʂ/.

The retroflex fricative **/ʂ/** is mastered by the age of 4.1-4.3 years in Malayalam (Neenu et al., 2011). The articulation of **/ʂ/** was worked upon in three participants in the present study i.e. **Sc** (9:1years/Female), **Kj** (11:6 years/Female) and **Ma** (8:5 years/Female). **Kj** substituted **/ʂ/** with dental stop /t/ in initial position and palatal affricate /c/ in medial position. **Sc** and **Ma** substituted /ʂ/ with dental stop /t/ in both initial and medial positions.

In the present study, correct production of **/ʂ/** was investigated in five vowel contexts: /a/, /i/, /u/, /o/ and /e/. As there were target words in both initial and medial positions, scores in both positions were combined to obtain a single score for each vowel context. Percentage of correct production was computed for five vowels for ten sessions. Mean, standard deviation, median and inter quartile range first (pre-therapy) and tenth sessions (post-therapy) are tabulated in Table 4.9.

Table 4.9.

Mean, standard deviation, median and inter quartile range of 1st and 10th sessions for /ʂ/ in five vowel contexts.

Vowel context	Score	Mean	SD	Median	IQR
/a/	**Pre-TS**	8.33	14.43	0.00	12.50
	Post-TS	80.56	9.62	75.00	8.33
/i/	**Pre-TS**	8.33	8.51	8.00	8.33
	Post-TS	66.67	14.43	75.00	12.50
/u/	**Pre-TS**	0.00	0.00	0.00	0.00
	Post-TS	83.33	16.67	83.33	16.67
/o/	**Pre-TS**	16.66	16.67	16.66	16.67
	Post-TS	94.44	9.62	100.00	8.34
/e/	**Pre-TS**	22.22	38.49	0.00	33.33
	Post-TS	88.89	9.62	83.33	8.33

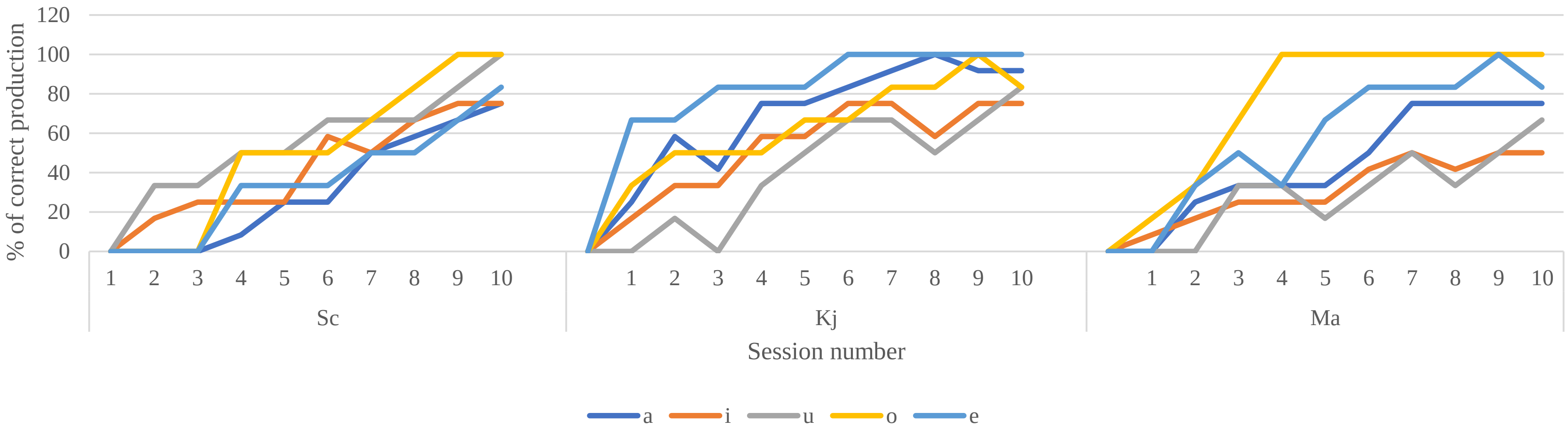
Note. SD=standard deviation, IQR=inter quartile range, Pre-TS=Pre therapy score, Post-TS=Post therapy score.

As observed from Table 4.9, pre-therapy scores were less than 16.66% in all the vowel contexts. Post-therapy scores were poorer in the context of /i/ and highest in the context of /o/. Post therapy scores of all vowels were higher than 80% except for vowel /i/ and /a/ where the scores were 75%. Variability in performance of participants was high in certain vowel contexts as indicated by standard deviation and interquartile range values.

For qualitative analysis, performances of **Sc, Kj** and **Ma** in various vowel contexts across ten sessions of therapy were represented in a line diagram as shown in Figure 4. 5.

Figure 4.5.

*Percentage of correct production of /ʂ/ across ten sessions for participants **Sc, Kj** and **Ma** in five vowel contexts*



As observed from Figure 4.5, vowel /o/ context resulted in better production of /ʂ/ in two out of three participants (**Sc** & **Ma**) and vowel /e/ in one participant (**Kj**). A specific order of vowel contexts could not be identified as the participants had variable performance across vowel contexts. It could also be inferred that the percentage of correct production scores increased in all vowel contexts as the sessions progressed.

To determine the facilitating vowel context for **/ʂ/,** minimum number of sessions for correct production (MNS-CP), minimum number of sessions for consistent correct production (MNS-CCP) and total number of sessions with correct production (TNS-CP) were computed from the graphs and tabulated in Table 4.10.

Table 4.10.

MNS-CP, MNS-CCP and TNS-CP values of three participants for /ʂ/ in five vowel contexts

Participant	Parameter	/a/	/i/	/u/	/o/	/e/
Sc	**MNS-CP**	-	-	7	**8**	10
	MNS-CCP	-	-	-	**8**	-
	TNS-CP	-	-	3	**3**	1
Kj	**MNS-CP**	6	-	10	7	**3**
	MNS-CCP	6	-	-	7	**3**
	TNS-CP	5	-	1	4	**8**
Ma	**MNS-CP**	-	-	-	**3**	6
	MNS-CCP	-	-	-	**3**	6
	TNS-CP	-	-	-	**8**	5

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

Similar to the observations in Figure 4.5, vowel /o/ resulted in faster learning of **/ʂ/** in two out of three participants (**Sc** & **Ma**) and vowel /e/ in one participant (**Kj**) as evident from Table 4.10. Minimum number of sessions for consistent correct production ranged from three to eight (MNS-CCP=3-8) for vowel /o/ and it was three sessions for vowel /e/ (MNS-CCP=3).

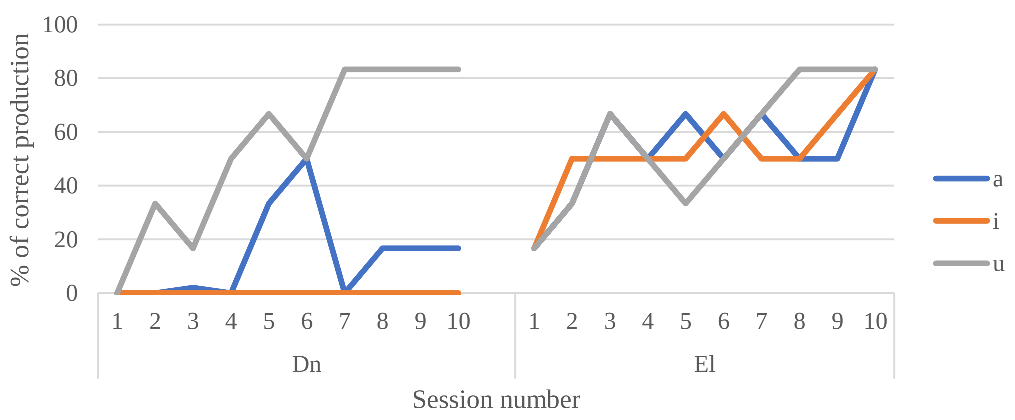
The vowels were arranged in the increasing order of MNS-CCP to obtain rank order of vowel contexts. As the overall performance of the participants were variable across vowel contexts, a specific rank order of vowel contexts could not be identified. To conclude, the production of **retroflex fricative /ʂ/,** was facilitated in the context of **mid back vowel /o/** (e.g. /***ʂo:***ppə/) in the present study.

4.1.6. Retroflex approximant /ɻ/.

The retroflex approximant **/ɻ/** is mastered by the age of 4.1- 4.3 years in Malayalam (Neenu et al., 2011). The articulation of **/ɻ/** was worked upon in **four participants** in the present study i.e. **Dn** (12:1 years/Female), **El** (12.5 years/Female), **Sc** (9:1years/Female) and **Ma** (8:5 years/Female). All the four participants substituted palatal glide /j/ for **/ɻ/**. Two participants (**Sc** & **Ma)** could not achieve the target criterion within ten sessions; hence their results will not be discussed in this section. Statistical analysis was not carried out for **/ɻ/** due to limited number of subjects and the findings will be described qualitatively. In the present study, correct production of **/ɻ/** was investigated in three vowel contexts: /a/, /i/ and /u/. Performance of the participants **Dn** and **El** across ten sessions in three vowel contexts are shown in Figure 4.6.

Figure 4.6.

*Percentage of correct production of /ɻ/ across ten sessions for participants **Dn** and **El** in three vowel contexts*



From Figure 4.6, it could be noted that both the participants had better production in the context of vowel /u/. Participant **Dn** could not produce **/ʐ/** correctly in the context of /i/ even after ten sessions of therapy. Interestingly participant **El** demonstrated comparable performance in the context of vowel /a/ and /i/.

MNS-CP (minimum number of sessions for correct production), MNS-CCP (minimum number of sessions for consistent correct production) and TNS-CP (total number of sessions with correct production) were computed for various vowel contexts to identify the facilitating vowel context and are tabulated in Table 4.11.

Table 4.11

MNS-CP, MNS-CCP and TNS-CP values of two participants for /ʐ/ in three vowel contexts

Participant	Parameter	/a/	/i/	/u/
Dn	**MNS-CP**	7	-	**7**
	MNS-CCP	-	-	**7**
	TNS-CP	3	-	**4**
El	**MNS-CP**	10	10	**8**
	MNS-CCP	-	-	**8**
	TNS-CP	1	1	**3**

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

From Table 4.11, it could be observed that both the participants (**Dn** & **El**) learnt the production of **/ʐ/** faster in the context of /u/. Minimum number of sessions required for the participants ranged from 7-8 (MNS-CCP=7-8). Participant **Dn** could not produce **/ʐ/** correctly in the other vowel contexts and participant **El** began to produce **/ʐ/** with targeted accuracy in other vowel contexts from tenth session onwards.

Vowel contexts were arranged in the increasing order of minimum number of sessions for consistent correct production (MNS-CCP) to determine the rank order of vowel contexts and the order is as follows: /u/ followed by /a/ followed by /i/. To conclude, the production of **retroflex approximant /ɻ/** was facilitated in the context of **high back vowel /u/** (e.g. /pu***ɻu***/) followed by **low central vowel /a/** (e.g. /ma***ɻa***/) followed by **high front vowel /i/** (e.g. /ku***ɻi/***) for the participants in the present study.

4.1.7. Unvoiced alveolar fricative /s/.

The alveolar fricative **/s/** is mastered by the age of 4.1-4.3 years in Malayalam (Neenu et al., 2011). The articulation of **/s/** was worked upon in four participants in the present study i.e. **Fm** (9.1years/Female), **Ma** (8.5 years/Female), **Kj** (11.6 years/Female) and **Es** (7.6 years/Female). **Fm** substituted **/s/** with palatal fricative /ʃ/, **Ma** and **Es** with palatal affricate /c/ and **Kj** with dental stop /t/. Participant **Es** could not meet the target criterion in any of the vowel contexts. Hence results of this participant are not discussed under results.

In the present study, correct production of **/s/** was investigated in the context of four vowels /a/, /i/, /u/ and /o/. Scores of vowel contexts in initial and medial positions were combined and percentage of correct production was computed for each vowel context. Mean, standard deviation, median and inter quartile range of first (pre-therapy) and tenth sessions (post-therapy) are tabulated in Table 4.12

Table 4.12.

*Mean, standard deviation, median and inter quartile range of first and tenth sessions for /**s**/ for four vowel contexts.*

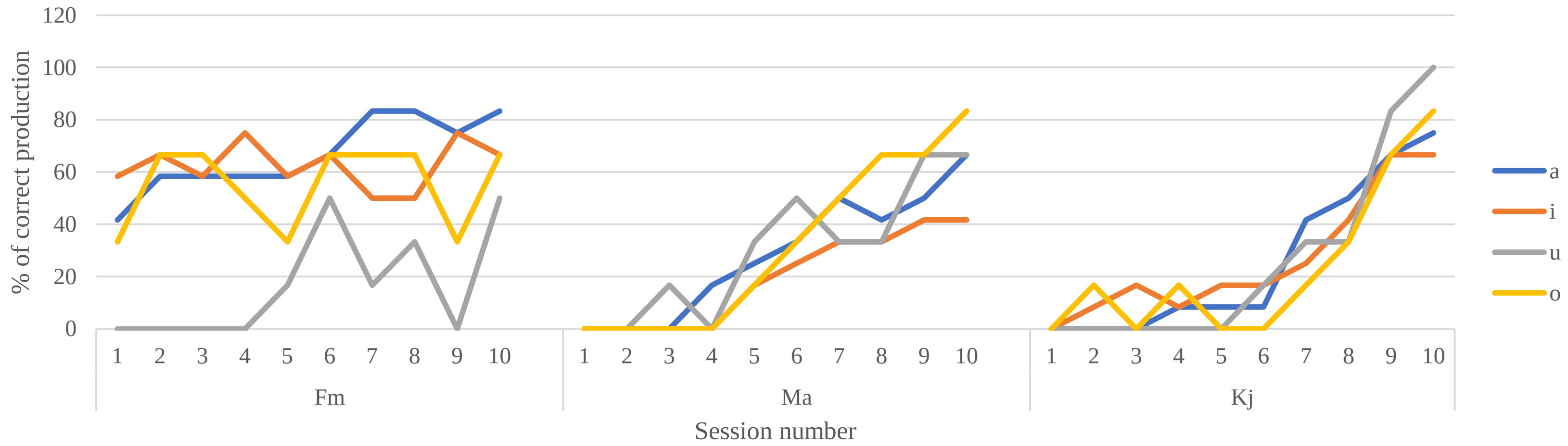
Vowel context	Score	Mean	SD	Median	IQR
/a/	**Pre-TS**	13.89	24.05	0.00	20.83
	Post-TS	75.00	8.33	75.00	8.33
/i/	**Pre-TS**	19.44	33.68	0.00	29.17
	Post-TS	58.33	14.43	66.67	12.50
/u/	**Pre-TS**	0.00	0.00	0.00	0.00
	Post-TS	72.22	25.46	66.66	25.00
/o/	**Pre-TS**	11.11	19.24	0.00	16.67
	Post-TS	77.77	9.62	83.33	8.33

Note. SD=standard deviation, IQR=inter quartile range, Pre-TS=Pre therapy score, Post-TS=Post therapy score.

From Table 4.12, it could be observed that the post-therapy scores of /s/ was lesser compared to the phonemes discussed previously. It was less than 85% in all vowel contexts. On comparing the post-therapy scores across vowel contexts, highest score was documented for /o/ and lowest for /i/. For qualitative analysis, performances of **Sc, Kj** and **Ma** in various vowel contexts across ten sessions of therapy were represented in a line diagram as shown in Figure 4. 7.

Figure 4.7.

*Percentage of correct production of /**s**/ across ten sessions for participants **Fm, Ma** and **Kj** in five vowel contexts*



On analysing the performance of three participants from Figure 4.7, the participants demonstrated variable responses across vowel contexts. Participant **Fm** demonstrated better scores for **/s/** in the context of /a/, participant **Ma** in the context of vowel /o/ and **Kj** in the context of /u/. In other words, a common facilitating vowel context could not be identified for alveolar fricative **/s/.**

MNS-CP (minimum number of sessions for correct production), MNS-CCP (minimum number of sessions for consistent correct production) and TNS-CP (total number of sessions with correct production) were computed for various vowel contexts to identify the facilitating vowel context and are tabulated in Table 4.13.

Table 4.13.

MNS-CP, MNS-CCP and TNS-CP values of three participants for ***/s/*** *in four vowel contexts*

Participant	Parameter	/a/	/i/	/u/	/o/
Fm	**MNS-CP**	**7**	-	-	-
	MNS-CCP	-	-	-	-
	TNS-CP	**3**	-	-	-
Ma	**MNS-CP**	-	-	-	**10**
	MNS-CCP	-	-	-	-
	TNS-CP	-	-	-	**1**
Kj	**MNS-CP**	-	-	**9**	10
	MNS-CCP	-	-	-	-
	TNS-CP	-	-	**2**	1

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

As observed from Table 4.13, three participants learnt to produce /s/ faster in three different vowel contexts; participant **Fm** in the context of /a/, **Ma** in the context of /o/ and **Kj** in the context of /u/. Based on these findings, facilitating vowel context could not be determined as it was different for each of the participant. To conclude, a facilitating vowel context for /s/ could not be identified from the present study.

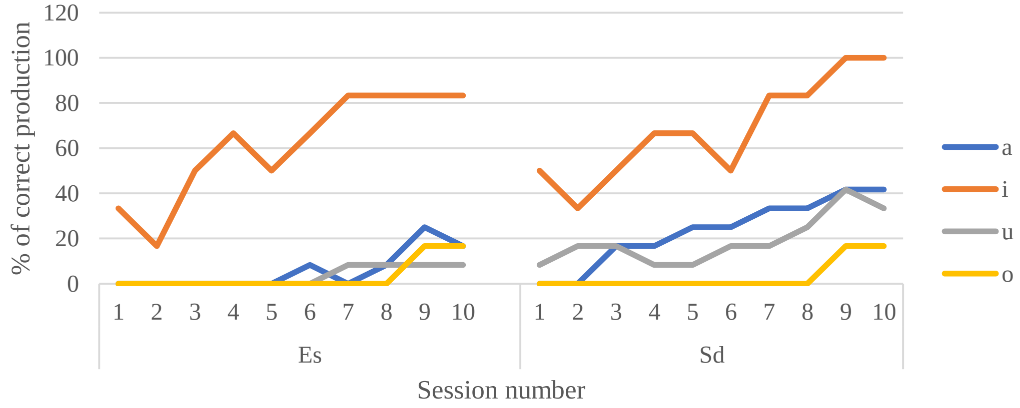
4.1.8. Alveolar tap /r/.

The alveolar tap **/r/** is mastered by the age of 4.1-4.3 years in Malayalam (Neenu et al., 2011). The articulation of **/r/** was worked upon in **five participants** in the present study i.e., **Es** (7.6years/female), **Sd** (8years/male), **Nj** (8.1 years/Male), **Kj** (11.6 years/Female) and **Fm** (9.1 years/Female). All the participants substituted **/r/** with palatal glide /j/. Participants **Nj, Kj** and **Fm** could not meet the target criterion. Hence results of these participants are not discussed in this section. Statistical analysis was not carried out for **/r/** due to limited number of subjects and the findings will be described qualitatively.

In the present study, correct production of **/r/** was investigated in the context of four vowels /a/, /i/, /u/ and /o/. Scores of each vowel in initial and medial positions were combined to obtain a single score for each vowel context and percentage of correct production was computed. Performance of **Es** and **Sd** across ten sessions in four vowel contexts are as shown in Figure 4.8.

Figure 4.8.

Percentage of correct production of ***/r/*** *across ten sessions for participants* ***Es*** *and* ***Sd*** *in four vowel contexts*



From Figure 4.8, it could be observed that both the participants had distinctly better scores in the context of vowel /i/. Participant **Es,** scores less than 20% in the contexts of /a/, /u/ and /o/. However, participant **Sd**, had better scores in the context of /a/ and /u/.

To determine the facilitating vowel context, MNS-CP (minimum number of sessions for correct production), MNS-CCP (minimum number of sessions for consistent correct production) and TNS-CP (total number of sessions with correct production) were computed for different vowel contexts and are tabulated in Table 4.14.

Table 4.14

MNS-CP, MNS-CCP and TNS-CP values of two participants for ***/r/*** *in four vowel contexts positions*

Participant	Parameter	/a/	/i/	/u/	/o/
Es	**MNS-CP**	-	**7**	-	-
	MNS-CCP	-	**7**	-	-
	TNS-CP	-	**4**	-	-
Sd	**MNS-CP**	-	**7**	-	-
	MNS-CCP	-	**7**	-	-
	TNS-CP	-	**4**	-	-

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

From the Table 4.14 it could be observed that both participants required least number of sessions for correct production of **/r/** in the context of /i/. Both participants learnt to produce **/r/** from seventh session onwards (MNS-CCP=7) and it was maintained for four consecutive sessions (TNS-CP=4). As the participants did not meet the target criterion in other vowel contexts, order of facilitating vowel contexts could not be established. To conclude, production of **alveolar tap /r/** was facilitated in the context of **high front vowel /i/** (e.g. /a***ri***/) in the participants of the present study.

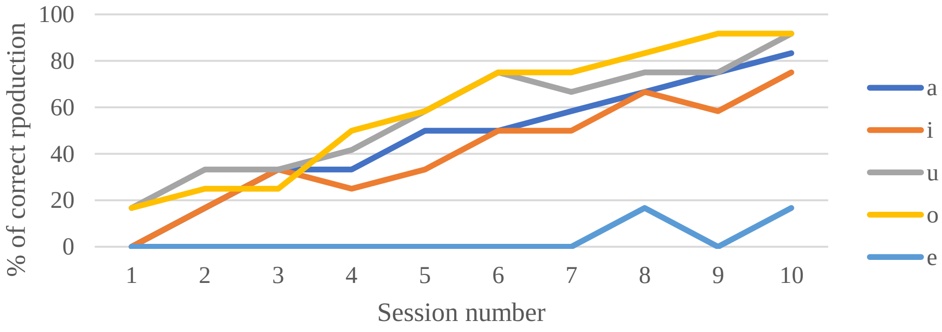
4.1.9. Alveolar trill /ṛ/.

The alveolar trill **/ṛ/** is mastered by the age of 4.1- 4.3 years in Malayalam (Neenu et al., 2011). The articulation of **/ṛ/** was worked upon in **two participants** in the present study: **Ma** (8:5 years/Female) and **Es** (7.6years/female. **Ma** substituted **/ṛ/** with voiced retroflex stop **/ḍ/** and Es substituted **/ṛ/** with /j/ in both initial and medial positions. Participant **Es** could not meet the target criterion within ten sessions. Hence the findings will not be discussed in the following section.

In the present study, correct production of **/ṛ/** was investigated in the context of five vowels: /a/, /i/, /u/, /o/ and /e/. The phoneme **/ṛ/** had target words in both initial and medial positions, so the scores of each vowel contexts in initial and medial positions were combined to obtain a single score. Percentage of correct production was computed for five vowels across ten sessions. As the phoneme was worked upon only in one participant, results will be discussed qualitatively. Performance of **Ma** across ten sessions in five vowel contexts are as shown in Figure 4.9.

Figure 4.9.

*Percentage of correct production of /ɽ/ across ten sessions for participant **Ma** in five vowel contexts*



From Figure 4.9, it could be observed that the production of /**ɽ**/ was better in the context of /o/ followed by /u/ and /a/. Participant **Ma** had least scores in the context of /e/ where there was minimal improvement in the scores from first to tenth sessions. Percentage of correct production scores improved considerably as the sessions progressed in remaining vowel contexts.

To determine the facilitating vowel context, MNS-CP (minimum number of sessions for correct production), MNS-CCP (minimum number of sessions for consistent correct production) and TNS-CP (total number of sessions with correct production) were computed for different vowel contexts and are tabulated in Table 4.15.

Table 4.15

*MNS-CP, MNS-CCP and TNS-CP values of participant **Ma** for /ɽ/ in five vowel contexts*

Participant	Parameter	/a/	/i/	/u/	/o/	/e/
Ma	**MNS-CP**	10	-	10	**8**	-
	MNS-CCP	-	-	-	**8**	-
	TNS-CP	1	-	1	**3**	-

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

As observed from Table 4.15, participant Ma learnt the production of **/ṛ/** faster in the context of vowel /o/ followed by /a/ and /u/. In the context of vowel /i/ and /e/, participant could not meet the target criterion of 80% correct production in three consecutive sessions. Participant Ma required eight sessions to learn the correct production of **/ṛ/** in the context of vowel /o/ (MNS-CCP=8).

To determine the rank order of facilitating vowel contexts, vowels were arranged in the increasing order of MNS-CCP. The order of facilitating vowel contexts observed was as follows: /o/ followed by /a/ and /u/ followed by /i/ and /e/. To conclude, the production of **alveolar trill /ṛ/** was facilitated in the context of **mid back vowel /o/** (/si:**ṛo/**) followed by **low central vowel /a/** (/e.g. /ta:**ṛa:**və/) and **high back vowel /u/** (e.g. /ce**ṛu**tə/) in the present study.

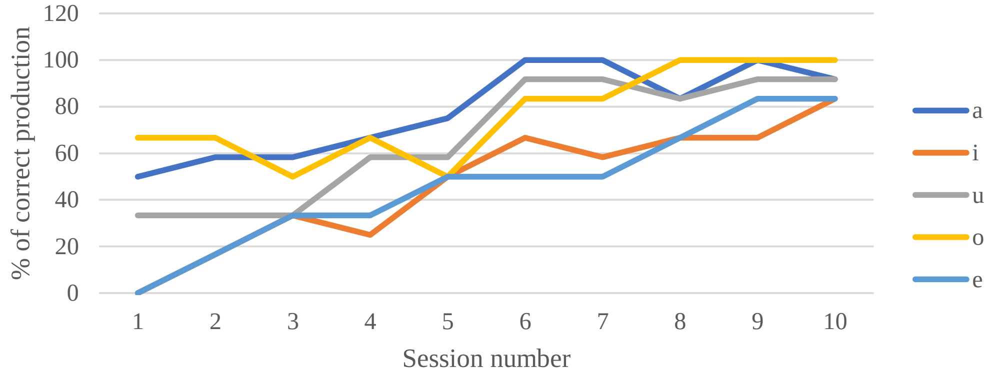
4.1.10. Unvoiced velar stop /k/.

The unvoiced velar stop **/k/** is mastered by the age of 3- 3.3 years in Malayalam (Neenu et al., 2011). The articulation of **/k/** was worked upon in one participant in the present study i.e., **Kj** (11:6years/Female). The participant **Kj** substituted unvoiced dental stop /t/ for **/k/**.

In the present study, production of **/k/** was investigated in the context of five vowels which include /a/, /i/, /u/, /o/ and /e/. Scores of each vowel context in initial and medial positions were added to obtain a single score for each vowel and percentage of correct production was calculated. Findings of **/k/** will be discussed qualitatively as there was only one participant. Performance of **Kj** in five vowel contexts across ten sessions of therapy are as shown in Figure 4.10.

Figure 4.10.

*Percentage of correct production of /**k**/ across ten sessions for participant **Kj** in five vowel contexts*



From figure 4.10, it could be noted that **Kj** performed better in the context of /a/ followed by /u/ and followed by /o/. Percentage of correct production scores improved in all vowel contexts considerably and the variability in production was relatively less.

To determine the facilitating vowel context, MNS-CP (minimum number of sessions for correct production), MNS-CCP (minimum number of sessions for consistent correct production) and TNS-CP (total number of sessions with correct production) were computed for different vowel contexts and are tabulated in Table 4.16

Table 4.16

*MNS-CP, MNS-CCP and TNS-CP values of participant **Kj** for /**k**/ in five vowel contexts*

Participant	Parameter	/a/	/i/	/u/	/o/	/e/
Kj	**MNS-CP**	**6**	10	**6**	**6**	9
	MNS-CCP	**6**	-	**6**	**6**	-
	TNS-CP	**5**	1	**5**	**5**	2

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Sessions in bold indicates facilitating vowel context.

As evident from Table 4.16, participant **Kj** produced **/k/** with targeted level of accuracy (80% correct production) from session six onwards in the context of vowels /a/, /u/ and /o/ (MNS-CCP=6). It is interesting to note that these three vowels were equally facilitating the production of **/k/** unlike the other phonemes where only one most facilitating vowel could be identified.

As part of the second objective of the study to determine rank order of facilitating vowel contexts, vowels were arranged in increasing order of MNS-CCP. Most facilitating vowel contexts were /a/, /u/ and /o/ followed by /e/ and /i/ respectively. Hence it could be concluded that **low central vowel /a/** (e.g. /***ka***ɳɳə/), **high back vowel /u/ (**e.g. /***ku***ppi/**)** and **mid back vowel /o/ (**e.g. /***ko***kkə/**)** facilitated the production of unvoiced velar stop **/k/** in participant **Kj.**

4.2. Effect of phoneme position on correct production of phonemes in children with DS

Results of the third and fourth objectives of the study will be discussed in this section i.e. the effect of phoneme position and the rank order of phoneme positions. Among the 10 phonemes considered for intervention in the study, only seven phonemes (/ʈ, ɖ, r, ṛ, s, ʂ, k) had target words in both initial and medial positions for various vowel contexts. Hence, these seven phonemes were considered to study the effect of phoneme position. Scores of the vowel contexts in each phoneme position were combined to obtain a single score and percentage of correct production was calculated.

For qualitative analysis, responses of the participants in initial and medial positions across ten sessions were represented in a line diagram for respective phonemes. Minimum Number of Sessions for Correct Production (MNS-CP), Minimum Number of Sessions for Consistent Correct Production (MNS-CCP) and Total Number of Sessions with Correct Production (TNS-CP) were computed. Phonemes were grouped based on the facilitating phoneme positions after qualitative analysis and results will be discussed under respective phoneme positions.

4.2.1. Initial position.

Initial position facilitated the production of four phonemes among the seven phonemes considered. This includes voiced retroflex stop **/ɖ/,** unvoiced velar stop **/k/,** alveolar fricative **/s/**, and retroflex fricative **/ʂ/.** Findings of these phonemes including descriptive statistics and qualitative analysis will be discussed below. Mean, standard deviation, median and inter quartile range of first (pre-therapy) and tenth sessions (post-therapy) for **/ɖ/, /s/** and **/ʂ/** are tabulated in Table 4.17. Descriptive statistics of /k/ is not mentioned in the table as the phoneme was worked upon only in one participant. Hence, findings of /k/ are discussed qualitatively.

Table 4.17.

Mean, standard deviation, median and inter quartile range of 1st and 10th sessions for ***/ɖ/, /s/*** *and* ***/ʂ/*** *for initial and medial positions.*

Phoneme	Position	Pre-therapy scores				Post-therapy scores			
		Mean	SD	Median	IQR	Mean	SD	Median	IQR
/ɖ/	**Initial**	**24.58**	7.98	16.66	14.58	**91.67**	9.24	91.67	15.63
	Medial	21.87	16.45	16.66	28.13	86.46	7.61	83.33	14.59
/s/	**Initial**	**13.89**	24.05	0.00	20.83	**81.94**	6.37	83.33	6.25
	Medial	11.11	19.24	0.00	16.67	44.44	24.06	58.33	20.83
/ʂ/	**Initial**	**18.05**	24.41	8.33	22.92	**93.05**	4.81	95.83	4.17
	Medial	0.00	0.00	0.00	0.00	62.96	22.45	66.67	22.22

Note. SD=standard deviation, IQR=inter quartile range, Pre-TS=Pre therapy score, Post-TS=Post therapy score

On analysing the mean and median values of pre and post therapy scores of three phonemes, scores were higher in initial position. For voiced retroflex stop **/ɖ/**, scores increased from 24.58% to 91.67% with ten sessions of therapy indicating good progress. Similarly for alveolar fricative /s/, scores progressed from 13.89% to 81.94% and for retroflex fricative **/ʂ/,** from 18.05% to 93.05% in initial position. In medial position, progress was less compared to initial position. Overall variability of data was more as indicated by standard deviation and interquartile range values.

For qualitative analysis, responses of the participants across 10 sessions in initial and medial positions were represented in line diagrams for each phoneme. Responses of the participants for /**ɖ**/, /**s**/, /**ʂ**/ and /**k**/ are shown in Figure 4.11, 4.12, 4.13 and 4.14 respectively.

Figure 4.11.

Percentage of correct production of /ɖ/ across ten sessions for participants ***Sj, An, Nj*** *and* ***Hd*** *in initial and medial positions.*

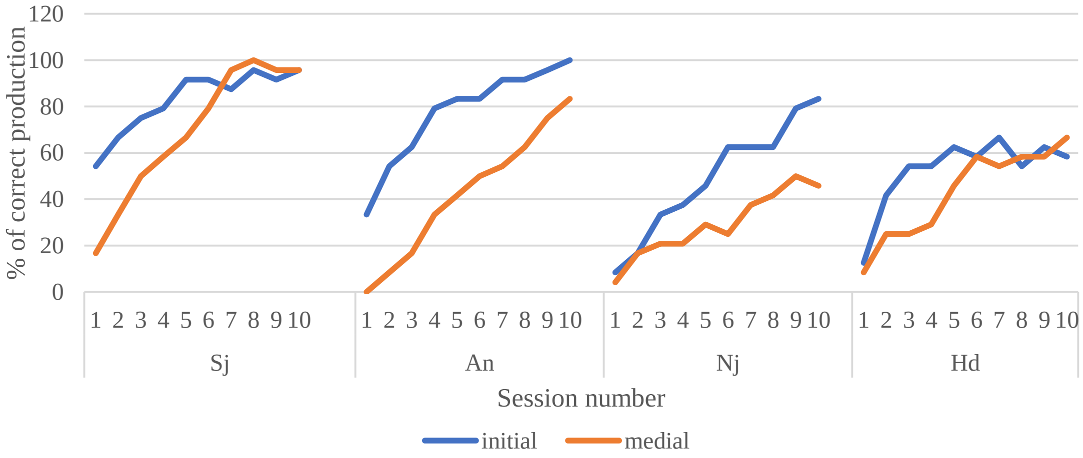


Figure 4.12.

Percentage of correct production of /k/ across ten sessions for participant ***Kj*** *in initial and medial positions.*

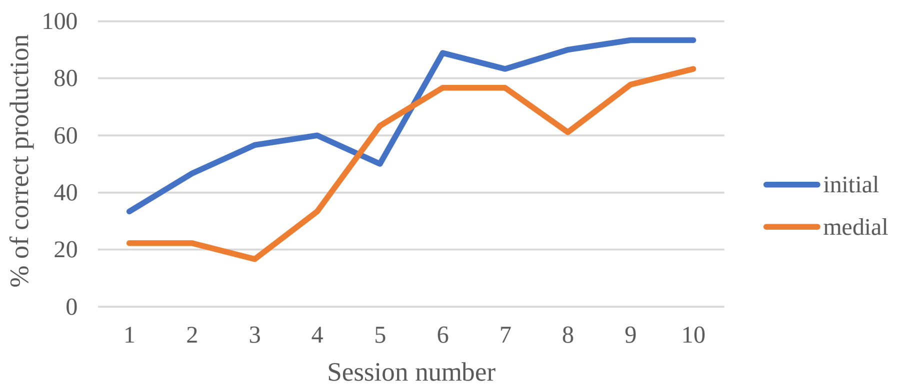


Figure 4.13.

*Percentage of correct production of /s/ across ten sessions for participants **Fm, Ma** and **Kj** in initial and medial positions.*

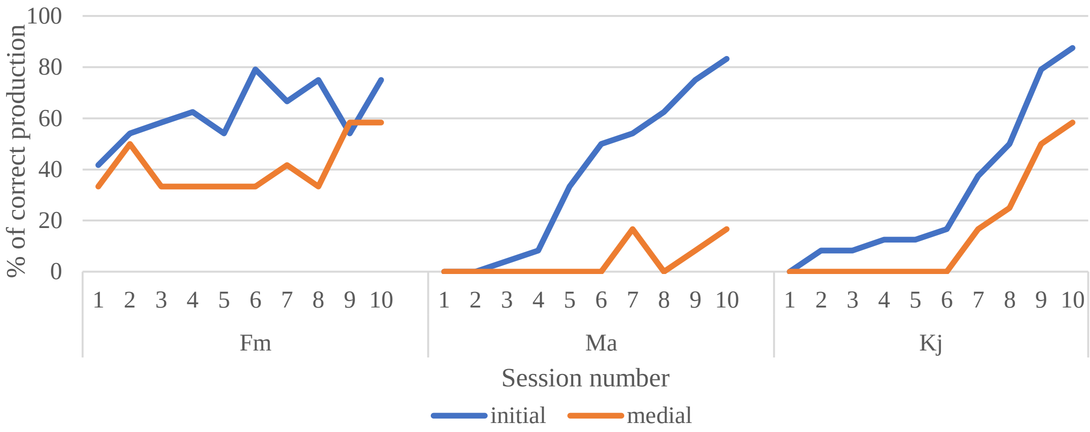
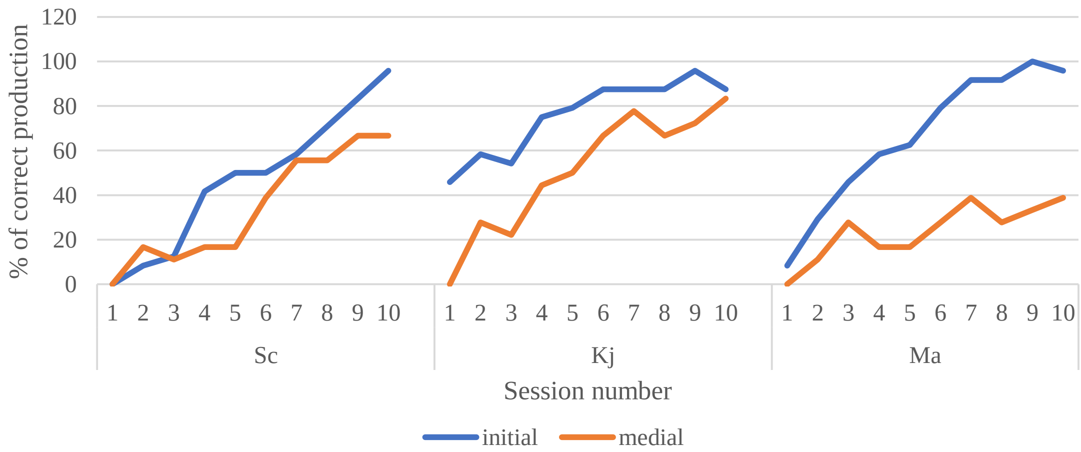


Figure 4.14.

*Percentage of correct production of /ʂ/ across ten sessions for participants **Sc, Kj** and **Ma** in initial and medial positions.*



From Figure 4.11, it could be noted that all four participants produced **/ɖ/** with better accuracy in lesser number of sessions in initial position compared to medial position. Similarly for velar stop /k/, initial position facilitated the correct production as indicated by better scores (Figure 4.12). As evident from Figures 4.13 and 4.14, for fricatives **/s/** and **/ʂ/,** all three participants scored better in initial position compared to medial position.

To determine the facilitating phoneme position, minimum number of sessions for correct production (MNS-CP), minimum number of sessions for consistent correct production (MNS-CCP) and total number of sessions with correct production (TNS-CP) were computed for **/ɖ/, /s/, /ʂ/** and **/k/** from the graphs as shown in Table 4.18.

Table 4.18

MNS-CP, MNS-CCP and TNS-CP values of four participants for ***/ɖ/, /k/, /s/*** *and* ***/ʂ/*** *in initial and medial positions*

Phoneme	Participant	Position	MNS-CP	MNS-CCP	TNS-CP
/ɖ/	**Sj**	**Initial**	**5**	**5**	**6**
		Medial	7	7	4
	An	**Initial**	**5**	**5**	**6**
		Medial	10	-	1
	Nj	**Initial**	**10**	**-**	**1**
		Medial	-	-	-
	Hd	**Initial**	-	-	-
		Medial	-	-	-
/k/	**Kj**	**Initial**	**8**	**8**	**3**
		Medial	6	-	3
/s/	**Fm**	**Initial**	-	-	-
		Medial	-	-	-
	Ma	**Initial**	**10**	**-**	**1**
		Medial	-	-	-
	Kj	**Initial**	**10**	**-**	**1**
		Medial	-	-	
/ʂ/	**Sc**	**Initial**	**9**	**-**	**2**
		Medial	-	-	-
	Kj	**Initial**	**6**	**6**	**5**
		Medial	-	-	-
	Ma	**Initial**	**7**	**7**	**4**
		Medial	-	-	-

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Facilitating phoneme positions are marked as bold

As evident from Table 4.18, three out of four participants learnt to produce **/ɖ/** faster in initial position compared to medial position. Number of sessions required for targeted percentage of correct production (80%) ranged from five to ten (MNS-CCP=5-10) in initial position and in medial position it was seven to ten (MNS-CCP=7-10). Hence initial position facilitated the production of voiced retroflex stop **/ɖ/** followed by medial position. For unvoiced velar stop **/k/,** in initial position participant **Kj** required eight sessions (MNS-CCP=8) to produce **/k/** consistently whereas, in medial position, consistent correct productions were absent.

For alveolar fricative **/s/**, in initial position two participants (**Ma** & **Kj**) required ten sessions to produce the phoneme with 80% accuracy. But in medial position, participants were unable to meet the target criterion even after 10 sessions. So, it could be inferred that it is better to teach **/s/** in initial position first followed by medial position. Retroflex fricative **/ʂ/** was learnt faster in initial position by all three participants in the present study. Minimum number of sessions to learn the production in initial position required ranged from six to nine (MNS-CCP=6-9). However, participants did not meet the target criterion in medial position. So similar to **/s/,** production of /**ʂ/** is facilitated in initial position.

To determine the order of facilitating phoneme positions of /**ɖ/, /s/, /ʂ/** and **/k/,** phoneme position with lowest MNS-CCP values was considered. From the tables and figures depicted above, it was initial position followed by medial position that facilitated the production of /**ɖ/, /s/, /ʂ/** and **/k/** in the present study. To conclude word **initial position** facilitated the production of **voiced retroflex stop /ɖ/, alveolar fricative /s/, retroflex fricative /ʂ/** and **unvoiced velar stop /k/** in the present study.

4.2.2. Medial position.

Among the seven phonemes considered for third and fourth objective, medial position facilitated the production of three phonemes. This includes unvoiced retroflex stop **/ʈ/,** alveolar tap **/r/** and alveolar trill **/ṛ/.** As the phonemes **/r/** and **/ṛ/** were worked upon in limited number of participants (two participants for **/r/** & one participant for **/ṛ/)**, descriptive statistical measures were not computed for these phonemes and the findings will be described qualitatively. Unvoiced retroflex stop **/ʈ/** was studied in four participants, so both descriptive statistics and qualitative analysis were done for **/ʈ/**. Mean, standard deviation, median and inter quartile range of first (pre-therapy) and tenth sessions (post-therapy) for **/ʈ/** is tabulated in Table 4.19.

Table 4.19.

Mean, standard deviation, median and inter quartile range of 1st, 5th and 10th sessions for /ʈ/ for initial and medial positions.

Vowel context	Score	Mean	SD	Median	IQR
Initial	**Pre-TS**	14.58	7.98	16.66	14.58
	Post-TS	86.46	9.24	83.33	15.63
Medial	**Pre-TS**	21.87	16.45	16.66	28.13
	Post-TS	91.67	7.61	91.67	14.59

Note. SD=standard deviation, IQR=inter quartile range, Pre-TS=Pre therapy score, Post-TS=Post therapy score

On comparing mean and median of pre and post-therapy scores, medial position had better scores compared to initial position. Mean pre-therapy scores were 14.58% in initial position and it increased to 86.46% during post-therapy whereas in medial position pre-therapy scores were 21.87% and post-therapy scores were 91.67%.

For qualitative analysis, responses of the participants across 10 sessions in initial and medial positions were represented in line diagrams for each phoneme. Responses of the participants for /ʈ/, /r/ and /ɽ/ are shown in Figure 4.15, 4.16 and 4.17 respectively.

Figure 4.15.

*Percentage of correct production of /ʈ/ across ten sessions for participants **Sj, Nj, Ak** and **An** in initial and medial positions.*

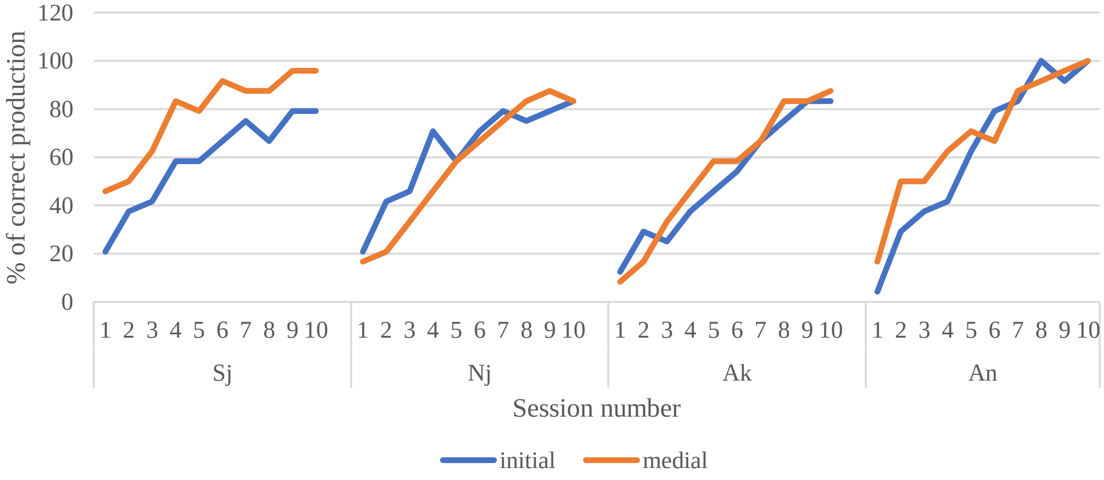


Figure 4.16.

*Percentage of correct production of /r/ across ten sessions for participants **Es** and **Sd** in initial and medial positions.*

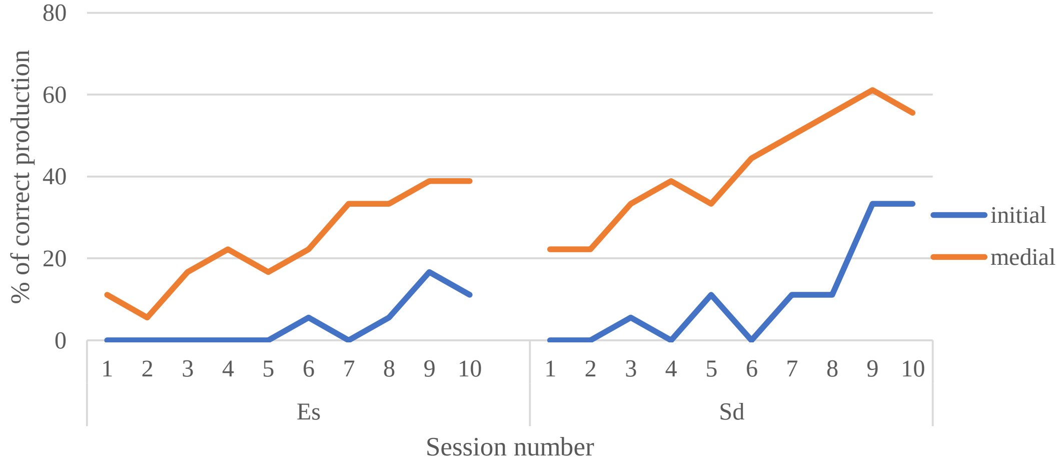
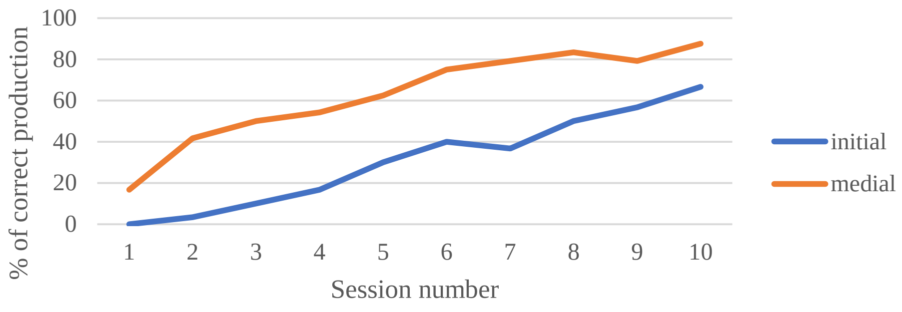


Figure 4.17.

Percentage of correct production of /ṛ/ across ten sessions for participant ***Ma*** *in initial and medial positions.*



On analysing the trend of the scores in initial and medial positions for /ʈ/, three out of four participants (**Sj, Ak & An**) performed better in medial position compared to initial position (Figure 4.15). One participant (**Nj**) had comparable scores in both initial and medial positions. For alveolar tap **/r/**, both the participants (**Es & Sd**) had distinctly better scores in medial position compared to initial position (Figure 4.16). However, the participants could not meet the targeted level of correct production (80% correct production) in both positions. The reason could be late acquisition of **/r/** even in typically developing children (Neenu et al., 2010) and **/r/** being one of the frequently misarticulated phonemes in Malayalam (Rofina & Sreedevi, 2018). For alveolar trill **/ṛ/,** participant **Ma** demonstrated better performance in medial position compared to initial position.

To determine the facilitating phoneme position, minimum number of sessions for correct production (MNS-CP), minimum number of sessions for consistent correct production (MNS-CCP) and total number of sessions with correct production (TNS-CP) were computed for **/ʈ/, /r/** and **/ṛ/** from the graphs and tabulated in Table 4.20.

Findings of **/r/** is not represented in the table as none of the participants could meet the target percentage of correct production within ten sessions of therapy

Table 4.20

MNS-CP, MNS-CCP and TNS-CP values of four participants for /ʈ/, /r/ and /ṛ/ in initial and medial positions

Phoneme	Participant	Position	MNS-CP	MNS-CCP	TNS-CP
/ʈ/	**Sj**	**Initial**	-	-	-
		Medial	**4**	**6**	**6**
	Nj	**Initial**	10	-	1
		Medial	**8**	**8**	**3**
	Ak	**Initial**	9	-	2
		Medial	**8**	**8**	**3**
	An	**Initial**	7	7	4
		Medial	7	7	4
/ṛ/	**Ma**	**Initial**	-	-	-
		Medial	**8**	**-**	**2**

Note. MNS-CP=minimum number of sessions for correct production, MNS-CCP= minimum number of sessions for consistent correct production, TNS-CP=total number of sessions with correct production. Facilitating phoneme positions are marked as bold

On analysing the number of sessions required to learn the phonemes in initial and medial positions from Table 4.20, medial position resulted in faster learning of **/ʈ/** and **/ṛ/.** Minimum number of sessions for consistent correct production for **/ʈ/** ranged from six to eight (MNS-CCP=6-8). For **/ṛ/**, the participant began to produce **/ṛ/** correctly by eight sessions (MNS-CP=8) and could maintain the production in two non-consecutive sessions (TNS-CP=2**).** In the case of alveolar tap /r/, although the participant demonstrated better performance in medial position, the participants could not meet the targeted level of correct production in both positions. To conclude,

medial position facilitated the production of **unvoiced retroflex stop /ʈ/, alveolar tap /r/** and **alveolar trill /ṛ/** in the present study.

4.3. Interaction of vowel context and phoneme

Fifth objective was to study the interaction or the combined effect of vowel context and phoneme position on correct production of phonemes. In the previous objectives effect of vowel context and phoneme position was analyzed separately. Hence an attempt was made to document the combined effect of these variables. Percentage of correct production was computed for each vowel context in initial and medial position separately across ten sessions of therapy unlike the previous objectives where the scores were combined with respect to vowel context or phoneme position.

Seven phonemes which had target words in both initial and medial positions were considered for this objective. This include unvoiced retroflex stop **/ʈ/**, voiced retroflex stop **/ɖ/,** retroflex fricative **/ʂ/,** alveolar fricative **/s/**, alveolar tap **/r/**, alveolar trill **/ṛ/** and unvoiced velar stop **/k/.** Facilitating vowel contexts and phoneme positions were identified in similar method used in previous sections. Facilitating contexts identified were compared with the findings of first (effect of vowel context) and third (effect of phoneme position) objectives to identify the interaction effect. Findings will be discussed under respective phonemes.

4.3.1. Unvoiced retroflex stop /ʈ/.

On analysing the performance of participants in different vowel contexts and phoneme positions, vowels **/o/** and **/u/** in **medial position** resulted in faster learning of **/ʈ/.** The number of sessions required for correct production of **/ʈ/** ranged from three to five for vowel /o/ (MNS-CCP=2-5) and two to five for vowel /u/ (MNS-CCP=3-5). In the previous sections where the independent effect of vowel contexts and phoneme positions were checked, vowel /u/ and medial position were found to be facilitating. On studying the interaction of vowel context and phoneme position, an additional vowel (/o/) was found to facilitate the production of **/ʈ/** in **medial position.**

4.3.2. Voiced retroflex stop /ɖ/.

When the performance of the participants was analyzed in initial and medial positions across vowel contexts, it was revealed that vowel /o/ in initial position resulted in faster learning in three out of four participants. Two participants demonstrated faster learning in the context of vowel /u/. Number of sessions required for correct production of **/ɖ/** ranged from two to six sessions for vowel /o/ (MNS-CCP=2-6) and two to three sessions for vowel /u/ (MNS-CCP=2-3).

On examining the effect of vowel context and phoneme position independently, it was vowel /o/ and initial position that facilitated the production of **/ɖ/.** When the interaction of vowel context and phoneme position was considered vowel /u/ along with /o/ facilitated the production**/ɖ/**. Initial position was leading to correct production in both conditions.

4.3.3 Unvoiced retroflex fricative /ʂ/.

Analysis of interaction of vowel context and phoneme position (combined effect of vowel context and phoneme position) revealed that each of the participants learnt the production of **/ʂ/** faster in initial position but the vowel context were variable across participants. **Sc** learnt **/ʂ/** in the context of /i/ and /o/, **Kj** in the context of /a/ and /e/ and **Ma** in the context of /o/. In medial position, performance of the participants were poor compared to initial position.

It was interesting to note that facilitating vowel context could not be identified when interaction effect was considered whereas, analysis of vowel context irrespective of phoneme position revealed facilitatory effect of **vowel /o/** in the production of **/ʂ/. Initial position** facilitated the production of **/ʂ/** in both scenarios.

4.3.4 Unvoiced alveolar fricative /s/.

Analysis of number of sessions required for correct production revealed that two out of three participants learnt **/s/** earlier in the context of /i/ in initial position (**Fm** & **Kj**), whereas one participant learnt faster in the context of /a/ (**Ma**). Number of sessions required for consistent correct production was 2-8 sessions for /i/ (MNS-CCP=2-8) and 8 sessions for /a/ (MNS-CCP=8). In general, all the participants demonstrated poor performance in medial position compared to initial position.

In contrast to the findings observed for **/ʂ/,** facilitating vowel context could not be established when independent effect of vowel context was considered. However, vowel /i/ was found to be facilitating the production of **/s/** when combined effect of vowel context and phoneme position was considered. Similar to **/ʂ/,** initial position facilitated the production of **/s/** in both conditions.

4.3.5 Alveolar tap /r/.

Two participants considered for intervention of **/r/** required least number of sessions for correct production in the context of /i/ in medial position. Both participants learnt to produce **/r/** from seventh session onwards and it was maintained for four consecutive sessions (MNS-CCP=7, TNS-CP=4). In initial position, none of the vowel contexts could facilitate the production of **/r/** in both the participants.

Findings observed during analysis of interaction and independent effect of vowel contexts and phoneme positions were similar. Vowel /i/ and medial position facilitated the production of **/r/** in both the participants. To conclude, production of **alveolar tap /r/** was facilitated in the context of **high front vowel /i/** in **medial position** (e.g. /a***ri***/) in the participants of the present study.

4.3.6 Alveolar trill /ṛ/.

Production of **/ṛ/** was better in the context of **vowel /u/** in **medial position** in the participant studied. Overall improved production was noted in medial position compared to initial position. When independent effect of vowel context and phoneme position was considered, vowel /o/ was found to be facilitating. Medial position was beneficial in both conditions. To conclude, production of **alveolar trill /ṛ/** was facilitated in the context of **mid back vowel /o/** (e.g. /si**ṛo/**) and **high back vowel /u/** (e.g. /ce**ṛu**tə/) in **medial position.**

4.3.7. Unvoiced velar stop /k/.

Analysis of responses of the participant **Kj** showed that, in initial position, production of **/k/** was learnt in the context of vowel /a/ within four sessions (MNS-CCP=4) and participant required a greater number of sessions in other vowel contexts. In medial position, rate of learning was slower compared to initial position.

When the independent effect of vowel context was considered, three vowels were found to facilitate (/a/, /u/ & /o/) the production of **/k/.** Initial position facilitated the production of **/k/** in both scenarios.

4.4. Validation of results

For validation of results of phase 3, three Malayalam speaking children with Down syndrome (**Dy, Gd** & **Js**) participated in phase 4. The phonemes selected for intervention were **/ɳ/** and **/ɭ/** for **Dy**, **/ɭ/** for **Gd** and **/ɳ/** for **Js**. During validation facilitating context of the respective phonemes established in phase 3 were introduced to the participants. The performance of participants for retroflex nasal **/ɳ/** and retroflex lateral **/ɭ/** are as shown in Figure 4.18 and Figure 4.19 respectively.

Figure 4.18

Percentage of correct production of /ɳ/ in the context of ***/u/*** *across sessions for participants* ***Dy*** *and* ***Js***

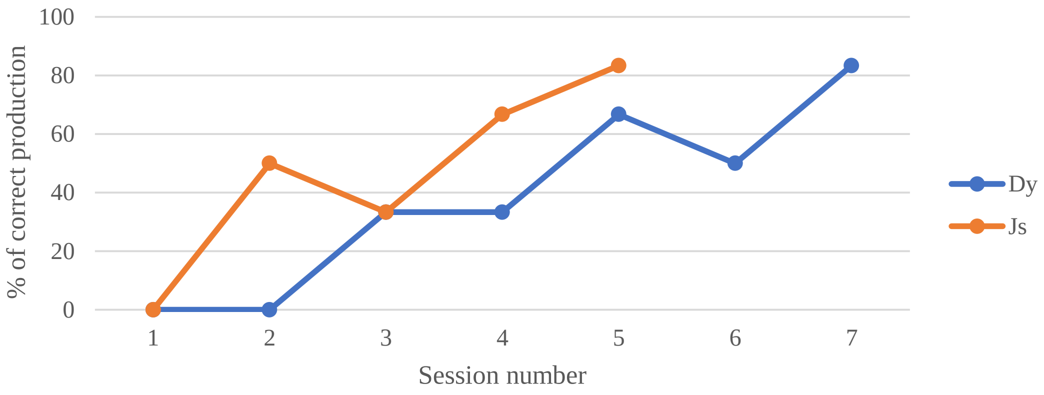
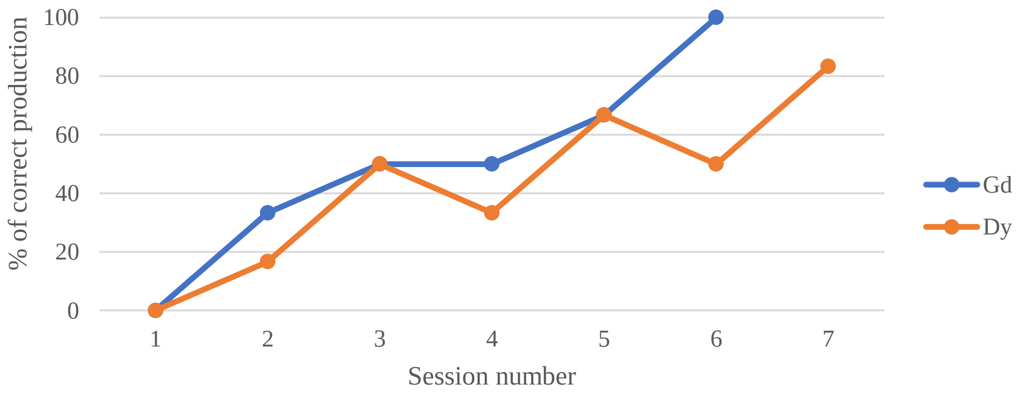


Figure 4.19

Percentage of correct production of /ɭ/ in the context of ***/u/*** *across sessions for participants* ***Gd*** *and* ***Dy***



From Figure 4.18, it could be observed that participant **Dy** achieved 80% correct production of **/ɳ/** by seventh session and participant **Js** by fifth session. Participants in phase 3 of the study required 3-7 sessions to achieve the target criterion. For retroflex lateral **/ɭ/,** participants **Gd** and **Dy** required six and seven sessions respectively to achieve the target percentage of correct production (Figure 4.19). Participants in phase 3 required 2-6 sessions to achieve the same. Hence it could be concluded that there is an effect of vowel context in the correct production of phonemes in children with DS.

Chapter 5: Discussion

The present study aimed to establish facilitating vowel contexts and phoneme positions for frequently misarticulated phonemes in Malayalam speaking children with Down syndrome. As explained in the results section, hypotheses were accepted as there was no significant difference in pre and post therapy scores indicated by the statistical tests. However, on qualitative analyses, it was observed that there is a reasonably large difference in pre and post therapy articulatory scores. Hence hypothesis testing using statistical tests were not useful in addressing the objectives of the study. Hence, the findings of the study will be discussed qualitatively under the following sections

- Effect of vowel context on correct production of phonemes in children with DS
- Effect of phoneme position on correct production of phonemes in children with DS

The study also attempted to document the interaction or the combined effect of vowel contexts and phoneme positions where vowel contexts were analysed in initial and medial positions separately. Facilitating contexts were identified through the analysis and compared with that of the independent effect of vowel context and phoneme position. Most of the phonemes had overlapping findings in both conditions. Hence the results of interaction will be discussed under the effect of vowel context and phoneme position separately.

5.1. Effect of vowel context on production of phonemes in children with DS

The first objective was to study the effect of vowel context on the correct production of phonemes in Malayalam speaking children with Down syndrome and the second objective was to determine the rank order of facilitating vowel context. Ten phonemes were considered under this objective and the phonemes were grouped according to the places of articulation for ease of discussion. The places of articulation considered included retroflexes, alveolars and velars**.**

5.1.1. Retroflex

Retroflex phonemes studied include unvoiced stop **/ʈ/,** voiced stop **/ɖ/,** fricative **/ʂ/**, nasal **/ɳ/**, lateral **/ɭ/** and approximant **/ɻ/.** A general conclusion that could be drawn from the results is that back vowels facilitated the production of retroflex phonemes in the present study. **High back vowel /u/** facilitated the production of unvoiced stop **/ʈ/,** nasal **/ɳ/,** lateral **/ɭ/** and retroflex **/ɻ/** whereas, **mid back vowel /o/** facilitated the production of voiced stop **/ɖ/** and fricative **/ʂ/.** Order of facilitating vowel contexts could not be established for **/ʈ/** and **/ʂ/.** For voiced stop **/ɖ/,** the order of vowel contexts was mid back vowel /o/ followed by high back vowel /u/. Interestingly, similar order of facilitating vowel contexts was documented for **/ɳ/, /ɭ/** and **/ɻ/** where, it was /u/ followed by /a/ followed by /i/.

Facilitation of retroflex production (**/ʈ/, /ɳ/**, **/ɭ/ & /ɻ/**) in the context of vowel /u/ could be explained through physiological basis of production of the vowel. During the production of vowel **/u/,** lips protrude, distance between the tongue and the palate reduces, and the whole tongue moves upward. This upward and backward movement of tongue makes it easier to combine /u/ with retroflex phonemes. Hence as explained by Swisher (1973), phonemes with similar articulatory features will facilitate the production of each other. This is also in agreement with the findings of a cross linguistic physiological study using ultrasound imaging in native typical speakers of Kannada, Hindi and Malayalam (Irfana, 2017). The study reported retroflex sounds are highly co-articulating in the context of following vowel /u/. Hence retroflex phonemes are produced more effortlessly in the context of vowel /u/ than other vowels. Findings of unvoiced stop **/ʈ/** and nasal **/ɳ/** are in consonance with a study conducted on similar lines in Kannada speaking children with speech sound disorder (Amulya, 2018). In this study also production of **/ʈ/** and **/ɳ/** were facilitated in the context of vowel /u/.

Facilitation of **unvoiced retroflex stop /ʈ/** in the context of vowel /u/ was in contrast with the results of Krishna and Manjula (1991). They reported that vowels /a/ and /i/ are facilitating the production of **/ʈ/** in Kannada. This could be due to the similarity in tongue height properties of /i/ and /u/ as both of these are high vowels which would have facilitated the production of retroflex **/ʈ/**. In addition to this, other significant contributing reasons could be the sample size and language studied. Despite both being case studies, the former study was in Kannada with a single participant, and the current study is in Malayalam and included four participants.

As mentioned before, production of **retroflex lateral /ɭ/** was facilitated in the context of **high back vowel /u/.** MRI studies revealed that lateral **/ɭ/** is produced by the anterior tongue body drawn upward and well inside the oral cavity, with the medial tongue occlusion appearing in the palatal region (Narayanan et al., 1999). This backward and upward placed tongue in the palatal region makes it easier to combine the phoneme with high back vowel like **/u/**. However, this finding is in contradiction with that of similar study in Kannada where vowels /i/ and /a/ facilitated production of **/ɭ/** in children with speech sound disorder (Amulya, 2018). The reason for high back vowel /u/ facilitating the production of **/ɭ/** in Malayalam as opposed to high front vowel /i/ in Kannada could be differences in tongue placement between these languages. MRI imaging studies documented that in Malayalam **/ɭ/** is produced with a more backed tongue body/ root compared to Kannada where the tongue root/body is more fronted (Kochetov et al., 2020). Ultrasound studies indicated that unvoiced Kannada retroflex have apical and voiced have sub-apical patterns while both voiced and unvoiced Malayalam retroflex have sub-apical pattern. (Sindhusha et al., 2014). These articulatory differences, in turn, are consistent with language-specific acoustic differences in laterals: higher F_2 for /ɭ/ than /l/ in Kannada (Kochetov et al., 2020), while lower F_2 for /ɭ/ than /l/ in Malayalam (Punnoose, 2011).

Retroflex approximant /ɻ/ is a unique phoneme present only in Malayalam and Tamil (Punnoose, 2011). It is one of the late acquiring (Neenu et al., 2010) and most misarticulated phoneme in Malayalam (Rofina & Sreedevi, 2018). Also **/ɻ/** is one of the most erred phonemes in children with DS (Anitha & Sreedevi, 2019). During the production of **/ɻ/,** the anterior tongue body was drawn upward and pulled inwards producing a pit like cavity in the middle of tongue body which was supported by bracing of the sides of the mid-tongue region against the palate. The narrowest tongue constriction appeared in the palatal region and posterior tongue had no bracing and was somewhat flat (Narayan et al., 1999). Also, retroflex approximant **/ɻ/** greater lip protrusions compared to other rhotics in Malayalam (Kochetov et al., 2020). Hence /u/ being a rounded vowel (lip protrusion) produced with upward and backward movement of tongue, it facilitated the production of **/ɻ/**. This is in accordance with the physiological reasoning for contextual facilitation where phonemes with similar articulatory features promote the correct production of each other (Swisher, 1973).

Mid back vowel /o/ facilitated the production of **voiced retroflex stop /ɖ/** and **retroflex fricative /ʂ/.** Facilitation of the phonemes in the context of /o/ could be attributed to backward placed tongue during the production of both the phonemes. Since tongue is already placed in a posterior position for the production of **/ɖ/** and **/ʂ/,** it will be easier to combine it with a back vowel like /o/. For **/ɖ/**, it was observed that vowel /u/ was the second facilitating vowel context following /o/. As explained in the previous section this could be due to similarity in tongue height properties of retroflex consonants and /u/. Similar findings for **/ɖ/** were also documented in Kannada (Amulya, 2018) where /u/ was the most facilitating vowel context.

Facilitation of **retroflex fricative /ʂ/** in the context of vowel /o/ is in consonance with the findings of Stokes and Griffiths (2010). They reported that in case of fronting errors, back vowels facilitated the production of **/ʂ/**. Two participants in the present study had fronting errors where **/ʂ/** was substituted with dental stop /t/. Hence back vowel /o/ would have aided the participants to achieve the correct place of articulation of **/ʂ/.**

To conclude the findings of retroflex stops, lateral, nasal and approximant phonemes, vowel /u/ facilitated the production of most of the phonemes. In a study on vowel production in young adults with DS, it was noted that production of /u/ is achieved by maintaining equal-sized front and back cavities, and not the complex tongue shape, that ensures the stable acoustics for /u/ (Carl, 2018). In this process of maintaining equal front and back cavities, the narrowing of vocal tract may be coinciding with that of retroflex phonemes. Also, the production of vowel /u/ is associated with more visible lip cues.

5.1.2. Alveolars

Alveolar phonemes studied include unvoiced alveolar fricative **/s/**, alveolar tap **/r/** and alveolar trill **/ṛ/.** Results indicated that vowel **/i/** facilitated the production of alveolar fricative **/s/** and alveolar tap **/r/** whereas, vowel **/o/** facilitated the production of alveolar trill **/ṛ/.** Order of facilitating vowel contexts for **/ṛ/** was as follows vowel **/o/** followed by **/a/** and **/u/** followed by **/i/** and **/e/.** However, order of facilitating vowel contexts could not be established for **/s/** and **/r/.**

High front vowel /i/ facilitated the production of **unvoiced alveolar fricative /s/** in the present study when the combined effect of vowel context and phoneme position was considered. Consistent facilitatory effect of vowel /i/ in the present study is in consonance with many earlier studies in English (Elbert & McReynolds, 1978; Zehel et al., 1972) and Kannada (Amulya, 2018) stating that vowel /i/ was facilitating the production of fricative **/s/**. This finding is attributable to the articulatory phonetics of **/s/** where the target is produced with articulatory gestures shared with vowel /i/, i.e., lips spread and tongue blade in high front position supporting Swisher's analogy (1973). The present findings are not in consonance with the perceptual study by Kalaiah and Bhat (2017) in Kannada where it was reported that vowels have least influence on fricative production. This discrepancy may be due to the population considered and language studied. The present study considered children and the perceptual study considered young adults and it is a known information that perception in children and adults vary (Nittrouer & Studdert-Kennedy, 1987).

Mazza et al. (1979) investigated the contextual effects on the inconsistency of /s/ production in 10 children with mean age 6 years 8 months misarticulating fricatives /s/ and /z/ interdentally in initial, medial, and final positions of words. The task involved repetition of sound-in-context-sentences and the vowel contexts comprised of /a/, /i/, and /u/. In contrast to the results of other studies, this study results revealed no vowel effect on the production of fricatives and this was attributed to the fact that fricatives are coarticulatory resistant.

In the present study, production of alveolar tap /r/ was facilitated in the context of **high front vowel /i/.** The reason for this could be the shared articulatory features of **/r/** and /i/. During the production of **/r/**, the tongue-tip constriction is in the pre alveolar region (Narayan et al., 1999). When **/r/** is followed by high front vowel /i/, the tongue is already in the pre alveolar region which is the articulatory gesture required for /i/. Hence minimal tongue adjustments are required for the production of /i/. According to the physiological reasoning proposed by Swisher (1973), facilitation arises due to the similarity in the articulatory phonetics of the error sound and its neighbouring sound. Bleile (2006) also documented that the production of consonantal **/r/** was facilitated when it occurs before high front vowel. Eisenson and Ogilvie (1983) have found that to teach the correct production of **/r/**, it has to be combined with an unrounded vowel.

In contrast to the findings of other alveolar phonemes in the present study, the production of **alveolar trill /ṛ/** was facilitated in the context of **mid back vowel /o/.** Magnetic resonance imaging studies have documented that the narrowest tongue-tip constriction was at the post alveolar region for **/ṛ/** which was more posterior compared to pre alveolar /r/ (Narayan et al., 1999). Here the tongue dorsum is free to move making it easier to combine with /u/.

5.1.3. Velar

The only velar phoneme studied was **unvoiced velar stop /k/**. Three most facilitating vowel contexts were documented for **/k/** which includes low central vowel /a/, high back vowel /u/ and mid back vowel /o/. Order of facilitating vowel contexts are as follows: vowels /a/, /u/ and /o/ followed by /e/ followed by /i/.

The facilitation of **/k/** in the context of **low central vowel /a/** could be attributed to the minimally interfering articulatory gesture of the vowel. During production of /a/, tongue is free to move in any direction without interfering with the upward movement of tongue dorsum for producing velar **/k/** (Bauman-Waengler, 2012). Ultrasound imaging studies in Malayalam have shown that vowel /a/ is least coarticulatory resistant with velars (Irfana, 2017). This is in accordance with physiological reasoning proposed by Swisher (1973) where the context that minimally interferes with the error sound facilitates its correct production and also vowel /a/ has less coarticulatory constraints (Sylak-Glassman, 2014). In addition to this, wide-open mouth posture during production of /a/ provides better visual feedback for the tongue dorsum movements of **/k/**. Studies in Malayalam speaking children with hearing impairment also reported facilitatory effect of /a/ in the production of velars (Anu Rose & Sreedevi, 2017). Amulya (2018) also reported /a/ as facilitating context for production of **/k/** in Kannada speaking children with speech sound disorder.

High back vowel /u/ and **mid back vowel /o/** also facilitated the production of /k/ along with /a/. This finding is in agreement with Bleile’s (1996) clinical observation reporting that velars are facilitated when positioned before back vowels. Bauman-Waengler (2012) reported that elevation of posterior tongue in back vowels facilitates the accurate placement of tongue required for /k/, if the error is an anterior constriction. Participant in the present study substituted /k/ with dental stop /t/. Hence back vowels /u/ and /o/ facilitated the correct production of /k/ in the present study. On observing the order of facilitating vowel contexts, high front vowel /i/ and mid front vowel /e/ were the least facilitating contexts. This finding in consonance with the clinical observation of Bauman-Waengler (2012) where incompatible vowels for the production of /k/ in case of fronting errors include /i/ and /e/. It was reasoned that high front tongue placement in vowels like /i/ and /e/ may revert back the faulty placement of tongue in fronting errors.

5.2. Effect of phoneme position on production of phonemes in children with DS

The third objective was to study the effect of phoneme position (initial & medial) on the correct production of seven frequently misarticulated phonemes (/ʈ, ɖ, k, s, ʂ, r, ṛ/) in Malayalam speaking children with Down syndrome and the fourth objective was to determine the rank order of phoneme positions. Initial position facilitated the production of four phonemes and this include voiced retroflex stop **/ɖ/,** unvoiced velar stop **/k/**, alveolar fricative **/s/** and retroflex fricative **/ʂ/**. Medial position facilitated the production of three phonemes: unvoiced retroflex stop **/ɖ/,** alveolar tap **/r/** and alveolar trill **/ṛ/**

5.2.1. Initial position

Facilitation of production of phonemes in initial position is in consonance with many previous researches. Branigan (1976) opined that initial position is advantageous for all consonants as consonants in initial position would receive the first neural commands and therefore be least influenced by preceding positions of the articulators. Other researchers also reported that a sound is easier to learn and should be taught in the initial-word position followed by the final-word position (Anderson & Newby, 1973; Van Riper & Emerick, 1984). In addition, initial syllables are relatively more stressed and are attended to and extracted perceptually by toddlers (Echols & Newport, 1992). Ghandour and Kaddah (2011) in their study on factors affecting stimulability reported that phonemes had highest stimulability in the initial position followed by medial and then final position.

Initial position facilitated the production of **/ɖ/** in the participants of the present study. The findings are in agreement with Bleile's (1996) clinical observation which states that voiced consonants are easily produced when present in the beginning of the syllable or word. Studies on articulatory acquisition in Malayalam reported that voiced retroflex **/ɖ/** was produced with better accuracy in initial position compared to medial position (Neenu et al., 2011).

Production of **unvoiced velar stop /k/** was facilitated in **initial position** in the present study. Developmental studies reported initial position favoring the acquisition of velars in Malayalam (Irfana & Sreedevi, 2012; Alphonsa & Sreedevi, 2012) and Kannada (Shishira & Sreedevi, 2016; Sushma & Sreedevi, 2016). Studies in English language also reported initial position resulted in correct production of /k/ (Scott & Milisen, 1954). This result is not in consonance with Bleile's (1996) findings reporting that final position favours velar production. As velars doesn't occur in word final position in Malayalam, this finding is not applicable to the language.

Alveolar fricative /s/ was facilitated in **initial position** in participants of the present study. The findings are in consonance with previous studies in Malayalam, where facilitatory effect of initial position was documented in children with hearing impairment (Merin & Sreedevi, 2017). Studies on articulatory acquisition in

Malayalam reported that greater percentage of children acquired fricative /s/ in the initial position followed by medial position by 4 years of age (Neenu et al., 2011). This result is also in agreement with previous research in other languages like English (Bennett & Ingle, 1984; Gallagher & Shriner, 1975; Scott & Milisen, 1954) and Kannada (Amulya, 2018). In English, acquisition of /s/ is found to be facilitated in the final position (Rockman & Elbert, 1984; Ferguson, 1975; Kent, 1982). As the occurrence of word final fricatives are limited to loan words in Malayalam, word final position was not considered in the present study.

Facilitation of production of **/ʂ/** in **initial position** in the present study is in consonance with previous studies in Malayalam. Neenu et al. (2011) documented that typically developing children acquired retroflex fricative **/ʂ/** in initial position before medial position. Merin and Sreedevi (2017) also reported that the production of **/ʂ/** was facilitated in initial position in Malayalam speaking children with hearing impairment.

5.2.2. Medial position

Medial position facilitated the production of **unvoiced retroflex stop /ʈ/** in the participants of present study. This could be attributed to the syllable structure of the stimuli words considered. In Malayalam, **/ʈ/** occurs in medial position as geminate clusters, hence they are produced as stressed syllables. However, in initial position, **/ʈ/** occurs as singletons which are unstressed. Literature reports geminates having longer duration and more extreme articulatory placements (Kent & Netsell, 1971). Such stressed syllables are perceptually distinct with enhanced motor and auditory feedback in children (Hoffman et al., 1980) making them facilitating for speech sound production. Another possible reason could be the perceptability of retroflexion. The word coda retroflex are reliably identified compared to word onset retroflex (Steriade, 2001).

Medial position facilitated the correct production of **alveolar tap /r/** in both the participants. Studies on phonological acquisition in Malayalam also reported that **/r/** was first achieved in medial position (Divya & Sreedevi, 2011). Curtis and Hardy (1959) found that the intersyllabic **/r/** (medial) was produced more correctly compared to **/r/** in the initial or final positions. Bleile (2006) also suggested teaching **/r/** between vowels i.e., in the intervocalic or medial position.

Medial position facilitated the production of **alveolar trill /ṛ/** in the present study. This finding is in consonance with articulatory acquisition in Malayalam. **/ṛ/** was produced correctly by greater percentage of participants in medial position compared to initial position (Neenu et al., 2011). Prathima and Sreedevi (2009) reported that trill **/ṛ/** was acquired earlier in medial position compared to initial position in Kannada. Shalini and Sreedevi (2016) observed that in Kannada, the production of trill **/ṛ/** was facilitated in the medial position compared to the initial position in a single case study of a child with speech sound disorder.

As it can be recalled from the beginning of the chapter, hypothesis testing was not useful in explaining the results of the current study. Hence, a qualitative analysis describing the performance of the participants was followed. Based on the findings of the study facilitating vowel contexts and phoneme positions could be established for the ten phonemes considered for intervention.

Chapter 6: Summary and Conclusions

The present study aimed to investigate the effect of vowel contexts and phoneme position on correct production of phonemes in Malayalam speaking children with DS. 15 children with DS (7 males & 8 females) served as participants for the study. Articulation therapy was given for 10 phonemes based on the articulatory errors of the participants. Four participants each received therapy for /ʈ/ and /ɖ/, five participants each for /ɳ/ and /ɭ/, three participants each for /s/ and /ʂ/, two participants each for /r/ and /ʐ/ and one participant each for /k/ and /ṛ/. Participants received 10 sessions of articulation therapy for each phoneme. Altogether, the participants received a total of 340 sessions for correct production of different phonemes.

Stimuli for the study included wordlist with target phoneme occurring in the context of five vowels in initial and medial position based on the phonotactics of Malayalam. Baseline production of the target phoneme was documented using as assessment wordlist. During intervention stage, participants were asked to repeat the stimuli words presented and on incorrect repetition, correct production of the target phoneme was taught using phonetic placement procedures. As it can be recalled from method section of the study, the therapy technique used was not a variable considered in the study. Wordlist was presented twice to the participants and on each presentation five opportunities were provided to learn the correct production in a particular phonetic context. The first production of each presentation was considered for analysis. Percentage of correct production was documented for each phonetic context across ten sessions.

The data was represented graphically for each participant to carry out visual analysis and also were subjected to non-parametric statistical analysis. Percentage of correct production scores of first and tenth sessions were compared using Wilcoxon signed rank test. Wilcoxon signed rank test did not show significance in spite of having maximum scores during post therapy in multiple contexts. Hence, non-parametric analysis was not apt and did not explain the findings of the present study appropriately as the definite change in the correct production of the target sound from the baseline was not evident from quantitative analysis. Therefore, the results are explained using graphical representations for each participant. Minimum Number of Sessions for Correct Production (MNS-CP), Minimum Number of Sessions for Consistent Correct Production (MNS-CCP) and Total Number of Sessions with Correct Production (TNS-CP) were computed from the graphs to identify the facilitating vowel contexts and phoneme positions. Apart from the independent effect of vowel contexts and phoneme positions, interaction of both the variables were also documented. Results of the analyses revealed the following contexts to facilitate the production of target phonemes considered (Table 6.1)

Table 6.1.

Summary of facilitating vowel contexts and phoneme positions for specific speech sounds in Malayalam in DS

Sl. No.	Phoneme	Vowel context	Order of facilitating vowel contexts	Phoneme position
1.	**Unvoiced retroflex stop /ʈ/**	/u/	CNE	Medial
2.	**Voiced retroflex stop /ɖ/**	/o/	/o/ > /u/	Initial
3.	**Retroflex nasal /ɳ/**	/u/	/u/ > /a/ > /i/	-
4.	**Retroflex lateral /ɭ/**	/u/	/u/ > /a/ > /i/	-
5.	**Retroflex fricative /ʂ/**	/o/	CNE	Initial
6.	**Retroflex approximant /ʐ/**	/u/	/u/ > /a/ > /i/	-
7.	**Alveolar fricative /s/**	CNE	CNE	Initial
8.	**Alveolar tap /r/**	/i/	CNE	Medial
9.	**Alveolar trill /ṛ/**	/o/	/o/ > /a/ = /u/ > /i/ = /e/.	Medial
10	**Unvoiced velar stop /k/**	/a/, /u/ & /o/	/a/ = /u/ = /o/ > /e/ > /i/	Initial

Note. CNE=Could not be established

The above results highlight the distinct effect of vowel contexts and phoneme positions on the production of speech sounds in children with DS. It was observed that the facilitating contexts varied across participants at times. This may be probably due to differences in intelligibility level, discrimination ability and type of errors. Certain disparities in facilitating contexts across languages as evident from the literature and present findings may be related to the differences in the phonotactics of a particular language.

The major merit of the study is that the internal validity was ensured by conducting continuous assessments during intervention. The findings of two phonemes /ɳ/ and /ɭ/ were replicated on other participants with DS to check for logical generality. Hence external generality is claimed through logical generality. However, it is recommended to validate the findings of other phonemes in a lager sample to precisely comment on the logical generality. These aspects increased the rigidity of the method used in the present investigation. The selection of facilitating contexts requires decision on stress, phoneme position, and permissible allophonic variation, frequency of occurrence, the effect of neighbouring sounds and the type of errors. SLPs are well-advised to test the child's production in various phonetic contexts and provide intervention accordingly. Also, an appropriate treatment approach must be chosen along with the facilitating phonetic contexts. Research on contextual facilitation is insufficient and replication of such studies is vital across languages. Clinical application of context based key environments is still in the emerging stages and such exercises are fundamental for evidence-based practice.

6.1. Implications

The results of the present study have notable benefits in the area of intervention of children with speech sound errors in Malayalam especially children with DS. The overall study and its results have implications both in terms of assessment and intervention of speech sound disorders. It highlights the importance of carrying out a detailed assessment and selecting appropriate vowel contexts and phoneme positions for the intervention of speech sound errors in children with DS as well as other clinical populations. Generally, contextual and positional effects are ignored during articulatory intervention of children with DS. The present findings serve as articulation therapy guidelines for SLPs in preparing stimuli with appropriate vowel contexts and phoneme positions for the intervention of different speech sounds. Also, with the knowledge of facilitatory vowel contexts and phoneme positions, speech sound production training can begin directly in those facilitatory contexts rather than in a trial-and-error manner with random contexts. This would undoubtedly serve as a quick guide and reduce the duration of articulatory intervention to ensure faster improvement in children with DS. Also, there is a dearth of such studies in other clinical population including speech sound disorders, hearing impairment etc. Findings of the present study could be extrapolated to such populations.

6.2. Future directions

- To validate the findings of the present study on larger sample size.
- To carry out similar studies in different clinical populations like Speech Sound Disorder, hearing impairment and other groups of intellectual disability.

- To investigate the effect of phonetic contexts on speech sounds in different languages.
- To explore the relationship between severity of the problem and the facilitating contexts.

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Appendices

Appendix I

Four criteria to bring rigidity in case study methods (Gibbert & Ruigrok, 2010)

Factors	**Criterion**	**Implementation in the present study**
Internal validity	1. To formulate a clear research framework 2. Analysis of patterns and triangulation of data (Eisenhardt & Graebner, 2007; Gibbert, Ruigrok, &Wicki, 2008; Yin, 2009)	Continuous assessment on every 5th session was conducted – correct production of the target observed in untrained words also
Construct validity	1. Solid description (Geertz, 1973) 2. Triangulation (Stake, 2000; Yin, 2009)	Provided in method section
External validity	3. Multiple cases 4. Rationale for case selection 5. Case study context	Had 15 participants; inclusion criteria provided; case study context with three data points pre- and post-intervention phases
Reliability	Transparency of research procedures	Inter-and intra-judge reliability was established (good-excellent level)

Appendix II

Phonemes considered for intervention and corresponding IPA symbols and Malayalam graphemes

No.	Phoneme	IPA	Grapheme
1.	Unvoiced retroflex stop	**/ʈ/**	ട
2.	Voiced retroflex stop	**/ɖ/**	ഡ
3.	Retroflex nasal	**/ɳ/**	ണ
4.	Retroflex lateral	**/ɭ/**	ള
5.	Unvoiced retroflex fricative	**/ʂ/**	ഷ
6.	Retroflex approximant	**/ʐ/**	ഴ
7.	Unvoiced alveolar fricative	**/s/**	സ
8.	Alveolar tap	**/r/**	ര
9.	Alveolar trill	**/ṛ/**	റ
10.	Unvoiced velar stop	**/k/**	ക

Appendix III

Stimuli words for assessment

Phoneme	Position	/a/	Gloss	/i/	Gloss	/u/	Gloss	/e/	Gloss	/o/	Gloss
/ʈ/	**Initial**	/ʈa:nkə/	Tank	/ʈi:ccar/	Teacher	-	-	/ʈembo/	Tempo van	/ʈo:mi/	A name
	Medial	/kuʈʈa/	Basket	/caʈʈi/	A vessel	/iʈʈu/	To put			/briʈʈo/	A name
/ɖ/	Initial	/ɖa:kini/	A cartoon charater	/ɖikki/	Dickey	/ɖunɖu/	Pet name	-	-	/ɖo:r/	Door
	Medial	/aɖa/	A snack	/ca:ɖi/	To jump	/kaɖukə/	Mustard	/eviɖe/	where		
/ɳ/	Medial	/kaɳɳa:ɖi/	Mirror	/tuɳi/	Cloth	/eɳɳuka/	To count				
/ɭ/	Medial	/taɭa/	An ornament	/puɭi/	Sour taste	/koɭuttə/	Hook				
/k/	Initial	/kappal/	Ship	/ki:ʃa/	Pocket	/kuʈʈi/	Child	/ke:ɖə/	Rot	/ko:ʈʈə/	Coat
	Medial	/cakka/	Jackfruit	/jimikki/	Ear ring	/mikku/	A name	-	-	-	-
/s/	Initial	/sadja/	Meal	/si:ttə/	Seat	/su:ppə/	Soup	-	-	/so:ja/	Soya
	Medial	/ke:sari/	Sweet	/i:si/	Easy			-	-	-	-
/ʂ/	Initial	/ʂa:ppə/	Shop	/ʂippə/	Ship	--	--	/ʂelf/	Shelf	/ʂo:ɭ/	Shawl
	Medial	/viʂam/	Poison	/miʂi/	Name	/ʈiʂu/	Tissue	-	-	-	-
/r/	Initial	/rat^{h}am/	Chariot	-	-	/rukku/	Pet name	-	-	/ro:gi/	Patient
	Medial	/viral/	Finger	/pu:ri/	An Indian food	/parun̪tə/	Kite				
/ṛ/	Initial	/ṛava/	Semolina	/ṛi:ttə/	Wreath	/ṛuppi/	Rupee	/ṛeɖi/	Ready	/ṛoʈʈi/	Bread
	Medial	/viṛakə/	Firewood	/muṛi/	Room	/kuṛukkə/	Porridge			/hi:ṛo/	Hero
/ʐ/	Medial	/paʐam/	Banana	/cuʐi/	Whirl	/kaʐuttə/	Neck	-	-	-	-

Stimuli wordlist for intervention

Phoneme	Position	/a/	Gloss	/i/	Gloss	/u/	Gloss	/e/	Gloss	/o/	Gloss
/ʈ/	Initial	/ʈajar/	Tyre	/ʈi:ppo/	Teapoy	-	-	/ʈe:ppə/	Tape	/ʈorccə/	Torch
		/ʈavval/	Kerchief	/ʈi:vi/	Television	-	-	/ʈebiɭ/	Table	/ʈoppə/	Top
		/ʈa:ppə/	Tap	/ʈikket/	Ticket	-	-	-	-	/ʈo:m/	Cartoon character
	Medial	/muʈʈa/	Egg	/peʈʈi/	Box	/caʈʈukam/	Spatula	-	-	/o:ʈʈo/	Auto
		/oʈʈakam/	Camel	/kuʈʈi/	Child	/kuʈʈu/	Child	-	-	/fo:ʈʈo/	Photo
		/poroʈʈa/	A flat bread	/caʈʈi/	A utensil	/cuʈʈu/	To cook	-	-		
/ɖ/	Initial	/ɖa:nsə/	Dance	/ɖi:sel/	Diesel	/ɖu:ɖu/	Cartoon character	-	-	/ɖo:ɭ/	Doll
		/ɖa:ɖi/	Daddy	/ɖingan/	Cartoon character	/ɖu:bi/	Cartoon character	-	-	/ɖo:kter/	Doctor
		/ɖappi/	Bottle			-	-	-	-	/ɖo:ra/	Cartoon character
	Medial	/kaɖa/	Shop	/aɖi/	Beat	/laɖu/	A sweet	/aviɖe/	There	-	-
		/vaɖa/	A Snack	/muɖi/	Hair	/kaɖuva/	Tiger	/iviɖe/	Here	-	-
		/kuɖa/	Umbrella	/o: ɖi/	Run	/uɖuppə/	Frock			-	-
/ɳ/	Medial	/aɳɳa:n/	Squirrel	/maɳi/	Bell	/taɳuppə/	Cold	-	-	-	-
		/eɳɳa/	Oil	/a:ɳi/	Nail	/vi:ɳu/	Fell	-	-	-	-
		/kiɳar/	Well	/to:ɳi/	Boat			-	-	-	-

Phoneme	Position	/a/	Gloss	/i/	Gloss	/u/	Gloss	/e/	Gloss	/o/	Gloss
/ɭ/	**Medial**	/vaɭa/	Bangle	/uɭɭi/	Onion	/veɭuppə/	White	-	-	-	-
		/ka:ɭa/	Bull	/kiɭi/	Bird	/ma:ɭu/	A pet name	-	-	-	-
		/viɭakkə/	Lamp	/paɭɭi/	Church	/mo:ɭu/	A pet name	-	-	-	-
/k/	**Initial**	/kaɳɳə/	Eye	/kiɭi/	Bird	/kuppi/	Bottle	/keʈʈə/	Knot	/ko:ʐi/	Hen
		/ka:lə/	Leg	/kiɳaɽ/	Well	/kutira/	Horse	/ke:kkə/	Cake	/kombə/	Horn
		/katti/	Knife	/kiʈʈi/	Got	/kuraŋŋə/	Monkey	/ke:ʈʈu/	Heard	/kokkə/	Crane
	Medial	/takka:ɭi/	Tomato	/kakkiri/	Cucumber	/cikku/	Sapota	-	-	-	-
		/kukkaɽ/	Pressure cooker	/i:rkkil/	Stick	/kukku/	A pet name	-	-	-	-
		/cikkan/	Chicken	/saikiɭ/	Cycle	/takku/	Pet name	-	-	-	-
/s/	**Initial**	/sa:ri/	Women's garment	/simham/	Lion	/su:rjan/	Sun	-	-	/so:ppə/	Soap
		/sa:mbaɽ/	Asouth Indian curry	/si:bɽa/	Zebra	/su:ci/	Needle	-	-	/so:sə/	Sauce
		/samo:sa/	A fried snack	/si:ɽo/	Zero			-	-	/so:fa/	Sofa
	Medial	/paisa/	Indian coin	/tulasi/	Basil	-	-	-	-	-	-
		/pa:jasam/	A dessert	/visil/	Whistle	-	-	-	-	-	-
		/ma:sam/	Month	-	-	-	-	-	-	-	-
/ʂ/	**Initial**	/ʂaɽʈʈə/	Shirt	/ʂi:ttə/	Sheet	-	-	/ʂe:kkə/	Shake	/ʂo:ppə/	Shop
		/ʂa:mpu/	Shampoo	/ʂi:ppə/	Sheep	-	-	/ʂe:ru/	A cartoon character	/ʂo:kkə/	Shock

Phoneme	Position	/a/	Gloss	/i/	Gloss	/u/	Gloss	/e/	Gloss	/o/	Gloss
/ʂ/	Medial	/viʂamam/	Sorrow	/maʂi/	Ink	/viʂu/	A festival	-	-	-	-
		/kaʂa:jam/	Ayurvedic medicine	/muʂi/	A fish	/aiʂu/	Name	-			-
/r/	Initial	/randɖə/	Two	-	-	/ruci/	Taste	-	-	/ro:mam/	Body hair
		/ra:tri/	Night	-	-	/ru:pa/	Indian currency	-	-	/ro:gam/	Disease
		/rasam/	South Indian soup	-	-	-	-	-	-	-	-
	Medial	/kara/	River bank	/ari/	Rice	/marunnə/	Medicine	-	-	-	-
		/vara/	Line	/ciri/	Smile	/uruɭa/	Rice ball	-	-	-	-
		/maram/	Tree	/sa:ri/	Women's garment	/kuruvi/	Sparrow	-	-	-	-
/ṛ/	Initial	/ṛaskə/	Rusk	/ṛibbaɳ/	Ribbon	/ṛu:mə/	Room	/ṛejil/	Rail	/ṛo:ɖə/	Road
		/ṛabbaṛ/	Eraser	/ṛimi/	A name	/ṛu:bi/	Ruby	/ṛe:ɖijo/	Radio	/ṛo:sə/	Rose
		/ṛa:ɳi/	Queen	-	-	-	-	-	-	-	-
	Medial	/ɟiṛa:fə/	Giraffe	/kaṛi/	Curry	/kaṛuppə/	Black	-	-	/poṛo:ʈʈa/	A flat bread
		/ta:ṛa:və/	Duck	/ceṛi/	Cherry	/ceṛutə/	Small	-	-	/si:ṛo/	Zero
		/ciṛakə/	Wing	/lo:ṛi/	Lorry			-	-	-	-
/ʐ/	Medial	/maʐa/	Rain	/vaʐi/	Path	/puʐu/	Worm	-	-	-	-
		/puʐa/	River	/kuʐi/	Pit	/maʐu/	Axe	-	-	-	-
		/va:ʐa	Banana tree	/ko:ʐi/	Hen	/kaʐuta/	Donkey	-	-	-	-

Appendix IV

Number of words in assessment and intervention wordlists

Sl. No	Phoneme	Assessment		Intervention	
		Initial	Medial	Initial	Medial
1.	/ʈ/	4	4	11	11
2.	/ɖ/	4	4	9	11
3.	/ɳ/	-	3	-	8
4.	/ɭ/	-	3	-	9
5.	/k/	5	3	15	9
6.	/s/	4	2	11	2
7.	/ʂ/	4	3	8	6
8.	/r/	3	3	7	9
9.	/ṛ/	5	4	11	10
10.	/ʐ/	-	3	-	9

Appendix V

Severity of intellectual disability and IQ scores (DSM IV-TR, 2000)

Severity of ID	Intelligence Quotient
Mild	50-69
Moderate	36-49
Severe	20-35
Profound	<20

Appendix VI

Bowen's Intelligibility Scale (2009)

1: completely intelligible in conversation

2: mostly intelligible in conversation

3: somewhat intelligible in conversation

4: mostly unintelligible in conversation

5: completely unintelligible in conversation

Percentage of Consonant Correct – Revised, PCC-R (Shriberg & Kwaitkowski, 1997)

1. Mild deviation - over 85% of correct consonants;

2. Mild-moderate deviation -between 85% and 66%;

3. Moderate-severe deviation- between 51% and 65%;

4. Severe deviation- less or equal to 50% of correct consonants

Appendix VII

Procedure for inter and intra personal discrimination

Minimal pairs and corresponding pictures were selected from the minimal pair based intervention manual for children with speech sound errors in Malayalam (Rofina & Sreedevi, 2018) based on the articulatory errors of the participants. Two minimal pairs were selected for each target phoneme.

Inter personal discrimination: The researcher imitated the error productions of the target sound exhibited by the participants and the participants were instructed to point to the appropriate picture from the pair of pictures presented.

Intra personal discrimination: For intrapersonal discrimination, the participants' error productions were audio recorded and played back to the participants. They were instructed to point to the appropriate picture from the pair of pictures presented.

The following rating was given for discrimination ability

Could not discriminate any of minimal pairs – Poor discrimination

Could discriminate at least one minimal pair – Fair discrimination

Could discriminate both minimal pairs – Good discrimination

Appendix VIII

All India Institute of Speech and Hearing, Manasagangothri,
Mysore, 570006

I, Ms. Anitha Naittee Abraham, Junior Research Fellow, am doing research on the correction of pronunciation of speech sounds in children with Down syndrome. During the course of research, I have to provide therapy for correcting the pronunciation errors of your child. There are no risks or discomforts involved during the study and also it will benefit in improving the speech clarity of your child. Audio and video recording of 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/student's participation in it. The possible benefits of my child's/student'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 without adversely affecting my/my ward's treatment at AIISH. I give my consent for my child's participation in this study.

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

(AGREE/DISAGREE)

Signature of Parent/Guardian | Signature of Investigator

(Name and Address) | (Name and Designation)