EFFECT OF VOWEL CONTEXTS AND PHONEME POSITIONS ON ARTICULATION OF PHONEMES IN CHILDREN WITH SPEECH SOUND DISORDER: PRE-POST THERAPY COMPARISON

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Doctor of Philosophy (Speech-Language Pathology)
To
The University of Mysuru
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August 2018

CERTIFICATE

This is to certify that the thesis entitled **"Effect of Vowel Contexts and Phoneme Positions on Articulation of Phonemes in Children with Speech Sound Disorder: Pre-post Therapy Comparison"** submitted by Ms. Amulya P. Rao, for the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysuru, Mysuru, was carried out at the All India Institute of Speech and Hearing, Mysuru.

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Vowel Contexts and Phoneme Positions on Articulation of Phonemes in Children with Speech Sound Disorder: Pre-post Therapy Comparison"** submitted by Ms. Amulya P. Rao, for the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysuru, 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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DECLARATION

This is to declare that the thesis entitled **"Effect of Vowel Contexts and Phoneme Positions on Articulation of Phonemes in Children with Speech Sound Disorder: Pre-post Therapy Comparison"** which is submitted herewith for the award of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysuru, Mysuru, is the result of my own study under the guidance of Dr. N. Sreedevi, Prof. of Speech Sciences, Dept. 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.

Mysuru
August 2018

Ms. Amulya P. Rao
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Dedicated to............

"Nandu amma"

"Nandu appa"

"Nandu Ma'am"

"Nanna muddu putaani participants haagu avara parents"

"Acknowledgements"

A team work always proves to be the best. I am the chariot of this thesis and many "saarathies" steered me during my journey. I hereby wish to express my deepest gratitude to all those "saarathies" who lead the chariot in the right direction along a smooth pathway.

Sreedevi mam, my guide, the best, I could ever have had. "Thanks" would be a very small word to express my gratitude to her. She was not only a guide, she was a mother, a friend who constantly believed in me and supported in each step of my thesis. There were ups and downs in the journey and both of us enjoyed each phase of it by learning a lot of lessons. Her constant and able guidance, support, blessings combined with her enviable calmness, patience and positivity served as the unfailing wheels of the chariot till the end.......Thank you so much mam.

Prof. S. R. Savithri, our beloved director; Dr. Santhosh. M. And Dr. Yeshoda made the journey smoother with their valuable suggestions. I heartily thank all the three of them.

Prof. Asha Yathiraj, the best course work mentor we could ever have. Thanks would be a very small work to express my gratitude to you ma'am. One word to describe you would be 'The Perfectionist'.

My little participants and their parents were the most wonderful participants I could ever have. Just one ring, they were there with me supporting and believing in me. Hope I have brought at least a satisfactory smile on their face during the course of intervention. Without them I could have not completed my work on time. 'Thanks a ton' is a very small gesture.........

Vasanthlakshmi mam, our best stats mam, like a magician made the statistical analysis easy with such complicated data!!!! Was it really that complicated ma'am!!!???......I deeply thank you mam for the support you have always given me.

Thanks to the staffs of DCS, especially bond staffs and staffs of phonology unit without whom I could have not find my subjects easily and quickly. Here, I should also thank my juniors in OPD and fellow clinicians (intervention) who constantly supported me in finding children with SSD. Please do not mind for not mentioning names as the list of people who have supported me goes pages to pages like an ocean with no ending point.

How can I forget those people who appeared like God at so many stages of my Ph.D. where I had almost lost hopes! And here comes my dearest JRF gang (AYPRADNNSDA) with whom I could not spend much time but they were the ones who were always there for my help. I would also like to thank Abhishek Sir and Sriraj Sir for their timely help without which I do not think could have submitted my thesis on time.

Here comes an opportunity to thank the ones who were the consistent positive pillars and wheels of my chariot, without whom, I could have not come to this destination. My family members: Amma, Appa, Doddamma, Maamas, in-laws, and Darshu. They all stood by me as positive pillars during my thesis phase. Thank you all........

Lastly, I would like to thank god almighty, for having provided me - the chariot- enough strength and robustness in reaching the goal.

Thank you one and all who have directly or indirectly helped me for my thesis..............

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Abstract

Phonemes are influenced by each other in speech and this phenomenon is termed coarticulation. Coarticulation is a function of contextual variations in the speech production process, i.e., certain contexts are described to be facilitatory to coarticulatory influence. Such facilitatory effect of neighboring sounds are studied in both typical and atypical phonetic development by various researchers. Earlier clinical-based researches investigated contextual influence on sounds to provide clinicians with the acquaintance of rule-governed behavior of contexts to facilitate the correct production of sounds. Most of the Western studies on contextual influence dating back to 1940s -1960s have limited sample size, confining to only few phonemes like fricatives/liquids which are high in frequency of ocurrence and errored in English; these studies are not extensive and intervention based. Extensive clinical observations on key environments in English are recommended for validation by replicating such studies. Clinical data reveals, velars, retroflex, trills, fricatives, and affricates to be the frequently erred sounds in Kannada and these are seldom addressed in phonetic context (vowel and phoneme position combination) studies. There are very few Indian studies targeting children with communication disorders on these lines. 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 in an individual. Owing to this, the present study aimed at establishing the facilitating vowel contexts and phoneme positions for the correct production of phonemes in children with SSD through articulatory intervention by employing a case study method.

In the present study, a total of 15 children with phonetic type SSD underwent intervention for articulatory errors. Among the 15 participants, 6 were enrolled for the

correction of /k/, 4 participants for /g/, 5 for /ʈ/, 5 for /ɖ/, 8 for /ɳ/, 3 for /ɭ/, 2 for /ʧ/, 3 for /ʤ/, and 3 for /s/.

The stimuli included bi-and tri-syllabic true words with target phonemes embedded in either in initial or medial position in one of the three vowel contexts, /a/, /i/, and /u/. For example if target phoneme is velar /k/, the stimuli were /***ka***ppe/, /***ki***vi/, /***ku***ɖi/, /a***kka***/, /a***kki***/, and /bu***kku***/. During intervention, the participants were asked to repeat the stimuli presented and on incorrect repetition, correct production of the same was trained using phonetic placement procedures. The number of correct responses and the minimum number of sessions required to attain 2/3 or 3/3 correct productions in three consecutive therapy sessions served as dependent variables and were documented. The data were visually analyzed for each participant using graphical representation. Application of inferential statistical procedures did not help in establishing the phoneme facilitatory contexts.

The results of the present study showed definite effect of vowel contexts and phoneme positions on correct production of phonemes in children with SSD. The overall study and its results have implications both in terms of assessment and intervention of speech sound disorders. 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 the established facilitatory contexts rather than in random contexts. This would undoubtedly reduce the duration of articulatory intervention and ensure faster improvement. The major merit of the study is, the articulatory intervention program was continued for all the 15 participants until they achieved the target phonemes and the three post intervention data points ensured the maintenance of the phonemes learnt.

Chapter 1: Introduction

Speech is a medium of communication involving a succession of processes initiating with a source, followed by a neural activity from the brain leading to movement of the articulators in the oral cavity and finally, propagation of sound waves. Speech constitutes fluency, voice, and articulation where fluency is the rhythmic movements of the speech articulators, voice is the sound wave produced due to the synchronized action of respiratory and laryngeal systems, and articulation is the physiological movements of speech articulators producing various speech sounds (Bowen, 2014).

During typical phonetic development (0-to 5-years), there is a gradual acquisition of speech sounds, beginning in the form of vegetative skills in neonates, gradually developing into rhythmic jaw movements during babbling stage and finally producing various adult-like CV syllables during toddler stage (MacNeilage & Davis, 1990). Certain phonetic contexts are reported to facilitate the production of specific speech sounds during typical speech development (Bleile, 1991, 1996, 2006; Bauman-Waengler, 2012).

Various studies on the effect of phoneme positions in typically developing children report facilitatory influence on the acquisition of speech sounds. Initial position is the highly facilitating context for majority of sounds in English, Quebecois French, and Dutch (Bleile, 2006; Dodd, Holm, Hua, & Crosbie, 2003; McLeod, Sutton, Trudeau, & Thordardottir, 2011; Smit, Hand, Freilinger, Bernthal, & Byrd, 1990; Stoel-Gammon, 1985; Watson & Skucanec, 1997b). Discrepancies are observed in findings of contextual effects on the acquisition of fricative /s/ and liquid /r/ across various studies. Few studies have reported initial position to be facilitating the acquisition of these sounds (e.g., /s/ -

Gallagher & Shriner, 1975b; /r/- Curtis & Hardy, 1959; Hoffman, Schuckers, & Daniloff, 1980; Magloughlin, 2016) and others have found final position to be more facilitating (e.g., /s/- Kent, 1982; /r/- McGowan, Nittrouer, & Manning, 2004; Stoel-Gammon, 1985; Smit, Hand, Freilinger, Bernthal, & Byrd, 1990; Templin, 1957).

Similarly, literature also reports on facilitatory influences of adjacent vowels and adjacent consonants in blends during typical phonological development. Frame content theory (Davis & MacNilage, 1995) reported that the acquisition of alveolars, velars, and bilabials are facilitated in the context of front, back, and central vowels respectively during the babbling stage. Stop blends (especially with front stop consonants) favored the production of trill /r/ than fricative blends (Curtis & Hardy, 1959). Clusters within word boundaries facilitated the production of fricative /s/ (Gallagher, 1975) and trill /r/ (Hoffman, Schuckers, & Ratusnik, 1977). Gick (1999) found approximant /ɹ/ facilitated in the context of fricative /ʃ/ preceding the target as in the word /ʃrink/.

Indian studies on typical speech development have also reported on the frequent occurrence of speech sounds in certain phoneme positions. In Kannada, initial position facilitated bilabials and velars; medial-position influenced palatals, dentals, and glottal sounds; palatal /ʃ/ was acquired in the initial position, whereas, dental /s/ in the medial position; and retroflex in both initial and medial positions in children aged between 12-to18- months (Shishira & Sreedevi, 2013), 18-to 24- months (Sushma & Sreedevi, 2013) and 2-to 6-years (Deepa & Savithri, 2010). In Malayalam, affricates /c/ and /ɟ/ are reported to be facilitated in the medial position earlier compared to initial. In contrast, fricatives /s/ and /ʃ/ are acquired first in the initial followed by medial-position (Divya, 2010; Neenu, 2011).

Compared to studies on the effect of phoneme positions, limited literature is available on the influence of vowels on the acquisition of speech sounds. Vowel [a] was highly preferred with a majority of the consonants and high front vowel [i] with dentals during babbling stage (Anjana & Sreedevi, 2008). Toddlers in the first fifty-word stage produced bilabials more often in the context of the central vowel, whereas coronals and velars in the context of high front vowels (Shishira & Sreedevi, 2013). These results are in agreement with the findings of Frame Content Theory (Davis & MacNielage, 1994). Irfana (2017) reported retroflex sounds in Kannada to be highly co-articulating in the context of following vowel /u/ compared to other vowels using ultrasound imaging.

Simultaneous to the facilitatory effect of phonetic contexts on speech sound acquisition, they are also responsible for the predictable articulatory errors during the developmental period which commonly leadto typical phonological processes or deviations (Fleming, 1971; Spriestersbach & Curtis, 1951; Snow, 1963). If these errors persist beyond a particular age range, it leads to speech sound disorders.

Speech sound disorders (SSD) is a broader term referring to a combination of intricacy in speech perception, speech-motor production, and the phonological representation of speech sounds and speech segments including phonotactic rules of the language and the prosody that impact speech intelligibility (ASHA, 2004b). The impact can be either on the formation of speech sounds resulting in articulation disorders or on the function of speech sounds within a language resulting in phonological disorders. ASHA (2004b) and Bernthal, Bankson and Flipsen (2009) recommends using speech sound disorder as a cover term, with the articulation/phonology dichotomy and notes that 'Intervention in speech sound disorders addresses articulatory and phonological impairments, associated activity and participation limitations, and context barriers and facilitators by optimizing speech discrimination, speech sound production, and intelligibility in multiple communication contexts' (Bowen, 2009, p. 42).

The prevalence rate of speech sound disorders is high (approx. 7.5%-18.6%) compared to other speech disorders in children (Cavalheiro, Brancilioni, & Keske-Soares, 2012; Census, 2011; Devadiga, Varghese, & Bhat, 2014; Jayashree, Arunraj, & Madhusudarshan, 2015; Karbasi, Fallah, & Golestan, 2010; McLeod & Harrison, 2009; Shriberg & Kwiatkowski, 1994). SSD is a significant communication problem in school-aged children (Pena-Brooks & Hegde, 2017). A survey by ASHA (2006) found 91% of SLPs working in public schools serving children with SSD. Mullen and Schooling (2010) reported 56% of school-based SLPs serving children with SSD. Literature found children with SSD to be at risk for either short-term or long-term difficulties in various domains such as, academics (writing and reading), social and emotional domains, that eventually impacts occupational opportunities in adulthood (Felsenfeld, Broen, & McGue, 1994; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004). Gillon (2004) reports literacy difficulties and phonological deficiencies strongly correlate. Children with severe phonological disorders have recurrently experienced problems in phonological awareness (Gillon, 2004); phonological representation (Nathan, Stackhouse, Goulandris, & Snowling, 2004; Stackhouse, 1997); reading (Bird, Bishop, & Freeman, 1995); and spelling (Clarke-Klein & Hodson, 1995). Also, incorrect production of speech sounds leads to speech unintelligibility posing a robust negative effect on social and emotional aspects as well. Findings of retrospective studies on co-occurring difficulties of SSD noted adults with phonological disorder in childhood having global challenges in retrieval, manipulation, and comprehension of linguistic information (Felsenfeld, Broen, & McGue, 1992; Felsenfeld, McGue, & Broen, 1995; Lewis, Ekelman, & Aram, 1989; Lewis & Freebrain, 1992). Felsenfeld, Broen, and McGue (1994) found 70% of the adults with a history of phonological disorders failed to earn a college degree and also held an unskilled job. These reports necessitates early identification and management of speech sound disorders.

Articulatory abilities are assessed using either screening or standardized articulatory tests and the errors documented are generally analyzed using Substitution Omission Distortion Addition (SODA) error or phonological process analyses. The PVM, distinctive feature or contextual-based analyses are prioritized least. Contextual-based analysis involves analyzing a particular speech sound in various phonetic contexts, vowel contexts and phoneme positions, by administering tests namely, the Deep test of Articulation (McDonald, 1964) in English, the Deep test of articulation Kannada-Sentence form (Rohini & Savithri, 1989), the Deep test of articulation Hindi – Picture (Deepa Shankar & Savithri, 1998), and so on.

Phonetic contexts in intervention are termed 'key environments' which facilitates the production of certain speech sounds according to the phonotactic rules of a language. Key environments can be neighboring vowels and consonants, phoneme position in a word, juncture, or cluster-combinations. A comprehensive contextual based analysis of speech sound errors provides a proper base for selecting the phoneme targets and the key-environments for the intervention of children with speech sound disorders.

Intervention stimuli of the target phoneme are prepared by randomly selecting words from daily conversations and children books. Generally, a phoneme is intervened first in the initial position followed by medial position and the vowel contexts are seldom considered in developing the stimuli. A few intervention-approaches based on the assumptions of contextual influences of sounds on each other like sensorimotor approach (McDonald, 1964), cycles approach (Hodson & Paden, 1983), and paired stimuli approach (Irwin & Weston, 1971) are in clinical use. Literature also supports the significance of considering phonetic contexts clinically (Bernthal & Bankson, 1981; Curtis & Hardy, 1959; House, 1981; Kent, 1982; Spriestersbach & Curtis, 1951; Swisher, 1973). Bleile (1991b, 2006) and Bauman and Wangler (2012) have provided the key environments within which the treatment targets can be established quickly in English. For example, alveolar stops at the beginning of words preceding front vowels voiced fricatives between vowels, and so on.

The earlier studies on contextual influence on speech sound acquisition in typically developing as well as children with speech sound disorders form the basis for all these assessment and intervention of articulatory errors on contextual bases. Numerous studies have also examined the influence of vowel contexts, blends, and phoneme positions on production of speech sounds in children with communication disorders.

Scott and Milisen (1954) have documented phonemes /f, z, s, k, l, v, r, g/ being produced correctly in either initial or final position than medial positions in children with articulation problems. Liquid /r/ was articulated more accurately in intersyllabic position than initial or final position (Curtis & Hardy, 1959). Rockman and Elbert (1984) reported final position to be more facilitating in the acquisition of fricative /s/ followed by initial and then medial positions. Ghandour and Kaddah (2011) found that the production of fricative /s/ and liquid /r/ in Arabic speaking children with dyslalia were facilitated more in the initial than final positions. Eisenson and Ogilive (1977) on applying the concept of co-articulation, reported the contexts of unrounded vowel and high-back vowel facilitating the acquisition of trill /r/ and velar /k/ respectively. Vowels /i/ and /a/ facilitated the acquisition of glide /j/ in a child with delayed receptive and expressive language substituting /l/ for /j/ (Stringfellow & McLeod, 1994). Stokes and Griffith (2010) validated the literature findings and reported that back vowels and word-final positions facilitated the production of fricative [ʃ]. Cleland, Scoobie, and Wrench (2015) reported back vowels facilitating the production of velar phonemes. Production of /s/ was easier in the context of clusters (/st, sn, sp, sk/) than in the context of vowel (Scott & Milisen, 1954). Similarly, consonant /r/ production was better in consonant blends than in singletons. Children with cleft lip and palate produced back-sounds effortlessly in the context of the cluster "-ed" at word endings (Peterson-Falzone, Trost-Cardamone, Karnell, & Jones, 2016).

The Indian literature in this area is in the nascent stage. Way back in 1989, Rohini and Savithri listed the vowel contexts facilitating the production of various Kannada speech sounds while developing the Deep test of articulation Kannada-Sentence form and Maya and Savithri (1990) for Malayalam phonemes during the development of Deep Test of Articulation Malayalam – Picture Form (1990). Krishna and Manjula (1991) on conducting a single case study found that vowels /i/ and /a/ facilitated the production of unvoiced retroflex /ʈ/. Anu Rose (2017) reported that the acquisition of velars /k/ and /g/ in children with hearing impairment was facilitated in the context of the vowel /a/. Another recent study by Merin (2017) reported that the acquisition of affricates and fricatives in Malayalam speaking children with hearing impairment progressed similarly as in typically developing children, with affricates facilitated in the medial-position and fricatives in the initial position.

1.1. Need for the study

Literature on behavioral studies regarding contextual influences have shown a definite effect of vowel contexts and phoneme positions on the production of speech sounds in both typically developing children and children with speech sound disorders. Stringfellow and McLeod (1994) and Stokes and Griffth (2010) report that application of phonetic contexts in intervention have shown speedy recovery in children with speech sound disorder.

There are several physiological, acoustical, and perceptual evidences supporting the behavioral 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; Subtenly, Oya, & Subtenly, 1972). Menon, Jensen, and Dew (1969) found vowels influencing the spectra of fricatives through acoustical evidence. Delattre, Liberman, and Cooper (1955) and Liberman (1957) through acoustic-perceptual studies found participants differentiating among voiced consonants /b,d,g/ from synthesized vowels based on the steady-state second formants that approximated the critical loci for bilabial, alveolar, and velar places of articulation. Spectral analyses of consonants revealed that the degree of variation in their acoustic properties is a function of vowel context (Fisher-Jorgensen, 1954; Halle, Hughes, & Radley, 1957; Zue, 1976).

The perceptual studies on differences between VOT of voiced and unvoiced stops showed contextual influences of vowels, consonants, and syllables (Klatt, 1975; Port & Rotunno, 1979). Coarticulatory effects of sounds are perceived as early as 22-months of age (Naeser & Lilly, 1970a). Magloughlin (2016), in a cross-sectional study on the acquisition of North American English /ɹ/ productions in children observed acoustic differences in target sound production attributing to the facilitatory contextual influences.

The feature of positional sensitivity is essential along with vowel and other consonant influences as there are strong statements in the literature concerning the advantages of phoneme position in acquisition and production of speech sounds. This is supported by the fact that vowels act differently in preceding and following contexts emphasizing the importance of phoneme position (Fowler & Brancazio, 2000; Irfana, 2017; Iskarous, Fowler, & Whalen, 2010; Ohman, 1966). Branigan (1976) reports initial position as "testing ground" for the acquisition of new sounds as they receive the first neural commands without being influenced by a previous articulatory position. In contrary to this finding, MacNeilage and DeClerk (1969) found final position to be more facilitating as they are minimally influenced by the articulatory requirements of neighboring sounds. Some phonemes have allophonic variations pre- and post-vocalic positions based on the articulatory phonetics of the vowels sensitizing the importance of considering the phoneme position (Kent, 1982).

Swisher (1973) provides two physiologic reasons for the facilitating effects of certain phonetic contexts on correct sound production. First, the context may be facilitating due to minimal interference with the error sound as in the sequence /sp/ where one is lingual and the other labial not interfering with others movements. Second, the facilitation arises due to the similarity in the articulatory phonetics of the error sound and its neighboring sound as in the cluster /st/ where upward movement of the tongue tip facilitates each other's production.

Contextual facilitation is also an essential procedure in implementing paired stimuli approach supporting generalization of target phonemes from facilitative to other contexts. 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, typically under 4- to 5-years of age, with speech sound disorders.

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; Irfana, 2017; Magen, 1984; Manuel, 1990; Manuel & Krakow, 1984). A recent study by Irfana (2017) on extent of coarticulation in Indian languages supports this finding by stating that, greater coarticulation is in the following vowel contexts than preceding contexts in Kannada, a Dravidian language whereas, a balanced co-articulation in both preceding and following contexts is noted in Hindi, an Indo-Aryan language. In addition, the co-articulation properties differ across sound classes (Ohman, 1966). A recent Indian study by Kalaiah and Bhat (2017) revealed within language differences in the influence of vowels on consonants in Kannada.

Variations in vowel influences can probably be because, co-articulation is language specific (Bladon & Al- Bamerni, 1976; Geng, 2010; Lindblom, Agwuele, Sussman, & Cortes, 2002; McAllister & Engstrand, 1992; Perkell, 1986; Sussman, Hoemeke, &

Ahmed, 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 concerning the degree of curvature and the exact location of constriction (Ladefoged & Maddieson, 1996; Svarny & Zvelebil, 1955; Ladefoged & Bhaskararao, 1983). Sindhusha, Irfana, and Sreedevi (2012) found unvoiced Kannada retroflex have apical and voiced have sub-apical patterns while both voiced and unvoiced Malayalam retroflex have sub-apical pattern using ultrasound tongue imaging studies.

Most of the Western studies on contextual influence dating back to 1940s -1960s have very less sample size, confining to only few phonemes, not extensive and not intervention based. On the other hand, few studies are extensive on only few target phonemes using single subject designs (Elbert & McReynolds, 1975, 1978) but focused on studying contextual influence during generalization phase on untrained stimuli. 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/ (Dewey, 1923; French, Carter, & Koenig, 1930) and /r/ (Carterette & Jones, 1974) as both are the most frequently occurring and erred sounds in English, leading to speech unintelligibility. Clinical data reveals, velars, retroflex, trill, fricatives, and affricates to be the frequently erred sounds in Kannada and these are seldom addressed in phonetic context (vowel and phoneme position combination) studies. There are only few Indian studies targeting children with communication disorders on these lines. Krishna and Manjula (1991) established the effect of vowels on correct production of Kannada unvoiced retroflex /ʈ/ on a single 15-year old gril; Anu Rose (2017) studied vowel influences on velar production and Merin (2017) examined phoneme position effects on affricate and fricative production in 6 Malayalam speaking children with hearing impairment. Even these Indian studies have focused on limited number of speech sounds on less number of both typical and atypical population. The influence of vowel contexts and phoneme positions on other cognates of retroflex (voiced, nasal and lateral), velars, affricates, and fricatives in Kannada are not established. Studies on typical speech development focus on speech production and not on contextual facilitation directly. Rohini and Savithri (1989) reports key environments for various Kannada phonemes, /ɖ, g, t, d, ɳ, ɭ, ʧ, ʤ, s, r/, except unvoiced velar /k/ and retroflex /ʈ/. 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 in an individual. "Such correct production may be 'nuggets of gold' to be used in speeding the establishment of correct habit patterns" (McDonald, 1964, p. 54) in therapy. Such knowledge on facilitating vowel contexts and phoneme positions guide SLPs in preparing appropriate stimuli for quick learning in children with speech sound disorders by reducing the cost and time.

1.2. The Current Study

Earlier studies on contextual facilitation are largely single case studies. Curtis and Hardy (1959) point out that the investigation of facilitating contexts requires detailed analysis as they generally differ across children. Also, the results obtained from group design studies on facilitating contexts are difficult to generalize to an individual (Zehel et al., 1972). In this concern, case study method was employed to test the hypotheses of the current study as well with a rationale to address both homogeneity and heterogeneity in the effect of vowel contexts and phoneme positions on the correct production of velars, retroflex, affricates, and fricatives in children with phonetic-type speech sound disorders. 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" (p.27). 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, Kenny, & Dickson-Swift, 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 (Barlow, Nock, & Hersen, 2009; Kazdin, 2011).

c) Allows for a highly accurate assessment of the impact on intervention for each 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)

f) The present study concerns establishing the facilitating vowel and phoneme position and not the efficacy of the therapy approach

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 provided in Appendix 2.

1.3. Aim

To establish the facilitating vowel context and phoneme positions on the production of speech sounds in native Kannada speaking children with speech sound disorder through articulatory intervention.

1.4. Objectives

1. To study the contextual effect of vowels /a/, /i/, and /u/ following the target phoneme at word level on the production of speech sounds in native Kannada speaking children with SSD through articulatory intervention.
2. To investigate the contextual effect of phoneme positions (initial and medial) at word level on the production of speech sounds in native Kannada speaking children with SSD through articulatory intervention.

1.5. Hypothesis

1. There will be no contextual effect of vowels /a/, /i/, and /u/ on the production of speech sounds in children with SSD on articulatory intervention.
2. There will be no effect of phoneme positions (initial or medial) on the production of speech sounds in children with SSD on articulatory intervention.

Chapter 2: Review of Literature

Communication is the essence of our lives. It is a process of exchanges of information, ideas, views, opinions, and thoughts in many ways from text messages, facial expression, gestures, to speech. Good communication involves the usage of socially acceptable speech and language skills. Language is a dynamic and complex system of conventional symbols representing thoughts and ideas (American Speech-Language-Hearing Association Committee on Language, 1983). The oral or verbal expression of thoughts and ideas is speech. American Speech-Language-Hearing Association (1993) divides speech into articulation, the act of motor production of speech sounds (Kent, 2015), fluency, smooth flow of speech, and voice (vocal quality, pitch, loudness, and resonance).

Articulation, in phonetics, is a peripheral motor process involving physiological movements of speech articulators (lips, tongue, hard palate, and soft palate) producing various speech sounds (Bauman-Wangler, 2009; Bowen 2014; Kent, 2015). Articulatory skill development relates body to mind progression (MacNeilage & Davis, 1990) involving gradual acquisition of the ability to move articulators in rapid and accurate manner. Articulatory role in neonates are vegetative in nature which gradually advances to rhythmic jaw movements during babbling stage and ultimately matures into precise production of sound sequences during toddler and pre-school stages. These sound sequences are continuous as the articulators are continually moving from one position to another and this process is termed coarticulation.

Coarticulation is a speech production process in which articulatory features, characteristics, and properties of one sound get modified by another sound (Sharf & Ohde, 1981). Coarticulation describes the concept that the articulators are continually moving into position for other segments over a stretch of speech (Fletcher, 1992). Co-articulation implies non-segmentation, or, at least, interaction of the presumed linguistic segments. Coarticulation process is bi-directional i.e., both preceding and following sounds will have effect on each other. The right to left coarticulation is termed anticipatory coarticulation (effect of dental nasal /n/ on the vowel /a/ in the word /pan/) and left to right coarticulation is termed carryover coarticulation (effect of dental nasal /n/ on the vowel /a/ in the word /nap/). The extent of compatibility or similarity between features (place/manner/voicing features) of adjacent sounds determines the accommodation present linking their productions. Feature spreading and feature reduction are the two basic modifications in the coarticulatory process. In the process of feature spreading, if same articulators are involved in the production of adjacent sounds, the inherent features of these sounds may become identical (/d/ is dentalized and devoiced when adjacent to /θ/ in "width") and if the articulators involved in the production of adjacent sounds are different then, there may be facilitation of transfer of a feature from one sound to another (transfer of lip rounding feature of /u/ on /t/ in "two"). In the process of feature reduction, the primary articulatory movement in producing a sound is influenced by neighboring sounds i.e., the articulators may not achieve the target position or there might be a shift in the target location under the influence of neighboring sounds. For example, vowels get centralized due to the influence of preceding and following sounds. Coarticulation is a function of contextual variations in the production process, i.e., certain contexts are described to be facilitatory to coarticulatory influence. Bilabial consonants have minimal influence on tongue positions of different vowels, whereas, alveolar consonants facilitate change in tongue location of back vowels.

Coarticulation is language specific to a large extent (Bladon & Al- Bamerni, 1976; Geng, 2010; Lindblom, Agwuele, Sussman, & Cortes, 2002; McAllister & Engstrand, 1992; Perkell, 1986; Sussman, Hoemeke, & Ahmed, 1993) as there are subtle changes in the physiological basis of speech sound production across languages. Extensive X-ray studies have shown that the retrofelxion varies in terms of degree of retroflexion and the exact location of constriction. In Hindi, it is apical post-alveolar retroflexion, whereas, in Tamil, it can be sub-apical post alveolar or palatal (Ladefoged & Maddieson, 1996; Svarny & Zvelebil, 1955; Ladefoged & Bhaskararao, 1983). In the Indian context, Sindhusha, Irfana, and Sreedevi (2012) found unvoiced Kannada retroflex have apical and voiced have sub-apical patterns while both voiced and unvoiced Malayalam retroflex have sub-apical pattern using ultrasound tongue imaging studies. Coarticulation appears to be conditioned by various factors, including stress, phonetic contexts, rate of utterance, and morphemic boundaries (Lindblom, 1963; Stevens and House, 1963; Lehiste, 1962). Stress raises fundamental frequency, increases duration, and increases intensity of the stressed word (Lehiste, 1970). These characteristics of stressed words produce a change in the physiologic, overlapping, ballistic movements of articulation (Perkins, 1971). It is feasible that these physiologic changes contribute to accurate production of a phoneme in a word that would otherwise be inaccurate. Coarticulatory effects are responsible for facilitatory influence of few phonetic features on the production of certain speech sounds and not others. Such phonetic features are termed, phonetic contexts.

2.1. Phonetic Contexts

Phonetic contexts also termed phonetic environments or key environments refer to the surrounding speech sounds of a target speech sound (Bleile, 1996). Contexts or environments can be adjacent sounds or breaks in sound either at the beginning or end of a syllable in a word or phrase. The surrounding speech sounds of a target can be a consonant or a vowel (e.g., if /k/ is the target in words /ske:l/, preceding fricative /s/ and following vowel /e/ along with the position of the target /k/ form the phonetic environments). Breaks are called junctures that are either within or across words (e.g., if /k/ is the target in /mikki mous/, the medial position of /k/ in the first word /mikki/, the following vowel /i/, the pause after the syllable /ki/ and the first consonant or syllable of the next word /mous/ are the surrounding phonetic environments of the target /k/).

There are many physiological, acoustic, and perceptual studies emphasizing on the contextual effects on the production and perception of speech sounds. The evidences at each level are described in the following section.

2.1.1. Physiological evidence.

The physiological studies on contextual effects on speech sound production have used various physiological techniques like EMG, X-ray, ultrasound, and articulograph. The results of various systematic examinations tongue muscles using EMG indicate the contextual influence for vowels and consonants in CVC syllables (MacNeilage & DeClerk, 1969). Fromkin (1966) found that the EMG activity for the production of bilabial /b/ in the initial position was greater than in final position. Gick et al. (2008) reported adult-like /ɹ/ being produced more in the post-vocalic position in typically developing 11-month old infants using ultra-sound imaging. In the Indian context, Irfana (2017) reported retroflex sounds in Kannada to be highly coarticulating in the context of following-vowel /u/ compared to other vowels using ultrasound imaging.

2.1.2. Acoustical evidence.

Spectral analyses data of consonants reveal that the degree of variation in their acoustic properties is a function of vowel context (Fisher-Jorgensen, 1954; Halle, Hughes, & Radley, 1957; Zue, 1976). Delattre, Liberman, and Cooper (1955) and Liberman (1957) found participants differentiating among voiced consonants /b,d,g/ from synthesized vowels based on the steady-state second formants that approximated the critical loci for bilabial, alveolar, and velar places of articulation indicating that vowels influence consonants. Menon, Jensen, and Dew (1969) found vowels influencing the spectra of fricatives through acoustical evidences. The differences between VOT of voiced and voiceless stops are influenced by contextual effects of vowels, consonants, and syllables (Klatt, 1975; Port & Rotunno, 1979). Dalston (1975) conducted acoustic study on 10 typically developing children and 5 adults. On comparison of children and adult data, investigator revealed children's correct productions of word-initial targets showing formants with same characteristic features as adults, including low mean F3 values (~2500Hz). This indicates that word initial positions are more facilitating for the production of sonorants. An Indian study by Manasa, Prathima, and Sreedevi (2007) reported longer duration of fricatives when followed by vowel /i/ due to assimilatory effect of the phonetic gestures of the vowel and the fricative /s/.

2.1.3. Perceptual Evidence.

Children as early as 22 months of age perceive the manner effect on vowel duration (Naeser, 1970a). Snow (1998) concludes that the key role in phonological development is by the relative perceptual salience of syllables. The development of syllables, especially weak syllables may depend on the prominence of the syllable, complexity of the word in which the syllable occurs, and the prosodic organization of the phrase containing the word (Rvachew & Brosseau-Lapre, 2018). Speech perception is influenced by the fine-grained acoustic details and their distribution within and across phonetic categories. Curtin and Zamuner (2014) reported that variations in salience of these acoustic details play a significant role in contrast perception. Infants do not have the knowledge of discrete phonetic categories. There is language-general speech perception till 6 months of age. A gradual shift from language general to language specific speech perception is observed between 6 months to 12 months of age.

Consonant recognition in various vowel contexts has been explored by several researchers (Dubno & Levitt, 1981; Redford & Diehl, 1999; Singh & Black, 1966; Wang & Bilger, 1973; Woods, Yund, Herron, & Ua Cruadhlaoich, 2010) and the patterns of vowel effects are inconsistent across studies. This discrepancy in results is attributed to the differences in the phonetic environment or the consonants being investigated in a particular language. English consonants reported to be more accurately identified in the context of vowel /a/ than /i/ or /u/ (Dubno & Levitt, 1981). Information transfer analysis has shown place of articulation to be identified less accurately before /i/ than before other vowels in English but, not in other languages (Singh & Black, 1966).Studies investigating the vowel effect on the position of consonant in consonant-vowel-consonant (CVC) and consonant-vowel (CV)/ vowel-consonant (VC) syllables report initial consonants to be identified more accurately than final consonants in the vowel context /a/, while final consonants in the context of vowel /i/.

A recent Indian study by Kalaiah and Bhat (2017) investigated the effect of vowels on the recognition of initial consonants in Kannada speaking adults. In general, the recognition of consonants was poorer in the context of vowel /i/, high in /o/, medium in /a/ and /u/ contexts. A reverse pattern has been observed in the Hindi where vowel /i/ had better identification scores compared to /a/ (Singh & Black, 1966). It was found that the pattern of vowel effect was similar in Kannada and English but the transfer of feature information was different across languages based on the cues provided by consonants in each language. The vowel contexts had least effect on nasal consonants, fricatives and stop consonants (/k/, /b/, /p/). Affricates were better perceived in the context of /i/ in English whereas it was poor in Kannada. This is attributed to the differences in the acoustical properties of speech sounds as a consequence of articulatory phonetics Kannada and English. Also, they attributed this to the differences in phoneme inventory between languages (Wagner & Ernestus, 2008). Feature analysis revealed majority of confusions and errors in perception was related to place of articulation and not manner or voicing feature. They concluded that each phoneme was affected differently in the context of different vowels.

2.2. Role of contextual facilitation in typical speech development

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 typical speech development.

2.2.1. Contextual effects of vowels on phonetic development in typically developing children.

Davis and MacNilage (1990) put forth Frame-Content Theory (FCT) to explain the contextual effects on speech sound development in typically developing children. According to FCT speech sounds/phonemes here, refers to the "content" and phonetic contexts refers to the syllable structures or "frames". The FCT describes context-based interactions of specific vowels and consonants, i.e. explains the vowel effect on consonant production. Consequently, the theory hypothesizes a robust interaction of labial, coronal, and dorsal sounds with central, front, and back vowels respectively in a CV syllable structure. The authors had conducted a single case study on English speaking toddler aged between 14-to20-months and inferred that the production of alveolar, velar, and bilabial sounds preferentially co-occurred with high front, high back, and low central vowels respectively. Subsequently in 2004, same authors found same results even in infants during babbling stage. Similar results were observed by Kern et al (2011) in French, Turkish, and Dutch babies as well. The Tunisian babies demonstrated coronal-front and labial-central co-occurrence patterns, but not dorsal-back co-occurrence, and the Romanian babies exhibited strong front-coronal co-occurrence patterns only.

Research conducted by de Boysson-Bardies (1993) on 10- to- 12 months old infants from French, English, Swedish and Yoruba language community confirmed the association of labials with central vowels in French, Swedish and Yoruba infants. Oller and Steffans (1993) observed similar consonant vowel co-occurrences in four 10-to-12 months' old children and a strong association was observed between coronals and high vowels and labials with low vowels.

Vihman (1992) found a significant association of labials with central vowels and velars with back vowels but, alveolars were not significantly associated with front vowels which were attributed to the consideration of central vowel /æ/ that complicated the results on alveolar- front vowel associations during babbling stage. These results were partially in agreement with the results of Davis and MacNeilage (1990). The authors reasoned this difference as due to the major role played by the lexical use of children considered in the study (as cited in Davis and MacNeilage, 1995).

The presence of phonological patterns for initial consonants in the context of front, central, and back vowels was investigated by To, Cheung and McLeod (2013) in children aged between 2.6-to-6.0 years. The phonological patterns either decreased or increased when associated with particular vowel contexts. Fronting of /k-/ to /t-/, stopping of /ʧ-/ to /t-/and /s-/ to /t-/ reduced in the contexts of back and front vowels respectively. Backing of /t-/ and /t^h-/ reduced in the context of front vowel with no statistical significance.

In the Indian context, Rohini and Savithri (1989) as part of the Deep Test of Articulation Kannada-Sentence Form, investigated the target consonants /g/, /ɖ/, /d/, /c/, /ɟ/, /ɳ/, /s/, /ʂ/, /h/, /j/, /r/, /ɭ/ and /v/ in preceding and following short and long vowel contexts /a/, /i/, /u/, /e/ and /o/ in Kannada speaking typically developing 5-to-9 year old children and listed the following facilitating vowel contexts for various target phonemes considered (Table 2.1).

Table 2.1.

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

Target phonemes	Age range	Key environments
/d/, /ɳ/, /r/, /v/, / ʂ /	5-to-6 years	/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/
/g/, /ɖ/, /c/, /ɟ/, /d/, /r/, /ɳ/, /s/	6-to-7 years	/a/, /i/, /u/, /e/, /o/
/ɭ/		/i/
/v/		/a/, /i/, /e/
/j/		/a/, /e/
/ʂ /		/a/, /u/, /i/
/h/		/a/, /i/, /o/, /e/
/g/, /ɖ/,/c/, /ɟ/, /r/, /d/	7-to-8 years	/a/, /i/, /u/, /e/, /o/

Table 2.1. Continued……

/v/	/a/, /i/, /e/
/j/	/a/, /e/
/s/	/a/, /i/, /u/, /o/
/h/	/e/, /i/, /o/
/ʂ/	/a/, /i/, /u/

Similarly, Maya and Savithri (1990) tested target consonants /s/, /ʃ/, /ʂ/, /r/, /ɭ/, /ɻ/, /ɾ/ and /j/ with preceding and following short and long vowels /a/, /i/, /u/, /e/ and /o/ and with preceding and following consonants /t/, /k/, /ʈ/, /m/, /n/, /p/, /c/, /l/, /j/, /h/, /r/, /v/, d/, /g/ in 5-to-8 year old typically developing children while developing The Deep test of articulation- sentence form developed by in Malayalam. The highly facilitating vowel environments in Malayalam is given in Table 2.2

Table 2.2

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

Target phonemes	**Age range**	**Key environments**
/s/, /ɻ/, /j/	5-to-6 years	/a/, /i/, /u/, /o/
/ʃ/, /ʂ/, /r/, /ɾ/		/a/, /i/, /u/, /e/, /o/
/ɭ/		/a/, /i/, /e/, /o/
/s/, /ʃ/, /ʂ/, /ɭ/,/r/, /ɾ/	6-to-7 years	/a/, /i/, /u/, /e/, /o/

Table 2.2. Continued..

/ɻ/, /j/		/a/, /i/, /u/, /o/
/s/, /ʃ/, /ʂ/,/ɭ/, /r/, /ɾ/, /ɻ/	7-to-8 years	/a/, /i/, /u/, /e/, /o/
/j/		/a/, /i/, /u/, /o/

A study by Anjana and Sreedevi (2008) in 6-to-12 month old infants supported the FCT (1990) results i.e. high front vowel [i], high back vowels, and central vowels often occurred with dentals, velars, and labials respectively. It was concluded that infants highly preferred on vowel [a] with a majority of consonants during babbling stage since [a] is a major 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. Also, in the first 50-word stage of toddlers, bilabials were produced more in the context of the central vowel /a/, while coronals and velars were produced in the context of the high front vowel /i/ (Shishira & Sreedevi, 2013).

Sushma and Sreedevi (2013) in 18- 24 months old Kannada speaking children, found a strong association of bilabials with central vowels, coronals with front vowels, and dorsal sounds with back vowels. In children aged 18-21 months, strongest association was between labials and central vowels which is in consonance with first hypothesis (pure frame: labial-central) of Frame Content Theory (Davis & MacNilage, 2004). Both the first and second hypothesis (pure frame: labial-central and front frame: alveolar- front respectively) were observed in children aged 21-24 months.

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 shed 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.

2.2.2. Contextual effects of phoneme positions on phonetic development in typically developing children.

Research investigating the effect of phoneme position on acquisition of various speech sounds report of differences across languages due to the phonotactic differences and minor variations in the physiological aspects of phoneme production. The terminologies in referring to the phoneme positions differ across studies based on whether the phoneme position is considered at the syllable (Curtis & Hardy, 1959; Hoffman, Schuckers, & Daniloff, 1980; Magloughlin, 2016) or word level (Bleile, 2006; Dodd, Holm, Hua, & Crosbie, 2003; Smit, Hand, Freilinger, Bernthal, & Byrd, 1990; Stoel-Gammon, 1985; Watson & Skucanec, 1997b). At syllable level, the phoneme positions are prevocalic, postvocalic, and intervocalic whereas at word level, the phoneme positions are initial, medial, or final. The following section includes description of studies carried out at both syllable and word level.

In English, most of the sounds are acquired first in the initial position of the word and then in the final position (Bleile, 2006; Dodd, Holm, Hua, & Crosbie, 2003; Smit, Hand, Freilinger, Bernthal, & Byrd, 1990; Stoel-Gammon, 1985; Watson & Skucanec, 1997b). The phonetic developmental pattern of Dutch is also similar to English with respect to vowels and singletons. Several studies propose preferential C-V combinations in babbling and early speech (Davis & MacNeilage, 1990, 2004; Anjana & Sreedevi, 2008).

Gallagher and Shriner (1975a) found no position effect with respect to lexical boundaries or phonological acceptability of the sequences on the production of fricatives /s/ and /z/ at sentence level in a 3-year old child. In contrast, the same authors, Gallagher and Shriner (1975b), established position effect on production of phonemes reporting that /s/ was accurately produced in the initial position of the word compared to final position for 34% of the times, whereas, /z/ was accurately produced in the final position of a word for 71% of the times at syllable level in three normal children aged 2- to 3- years 10 months having inconsistent production of /s/ and /z/. On the other hand, Kent (1982) made a contradictory observation to Gallagher and Shriner (1975b), that the fricative /s/ was easily produced in the word-final position compared to word-initial position. In agreement to the findings of Kent (1982), Kent and Bauer (1985) found that even one year old infants' production had more fricatives in the syllable final position than stops. The author justified this result with the fact that in the final-position a sound is minimally influenced by the articulatory requirements of the adjacent sounds and even the normal speech sound developmental pattern shows that fricatives are achieved in the final position prior to the initial position. Kent and Bauer (1985) also reported that liquid [ɹ] appeared first in the word-initial position than in the final and outnumbered fricatives. Toddlers of 2-years had highest consonant inventories in the word-initial position with exemplars from stops, nasals, fricative and glides whereas, final consonants involved majorly stops followed by nasals, fricatives, and liquids. Smit et al. (1990) also support the same findings in 3-9 years and McGowan et al. (2004) in 14-31 months typically developing children. In contrast, Templin (1957) and Stoel-Gammon (1985) report liquid [ɹ] produced first in the final position than initial during typical speech development.

There has been an inconsistent literature reports on the acquisition of North American English /r/ with respect to phoneme position. Few studies report that the liquid /r/ is acquired in the initial or prevocalic position (Curtis & Hardy, 1959; Hoffman, Schuckers, & Daniloff, 1980; Magloughlin, 2016). On the other hand, more studies report that it is acquired in the final or post-vocalic position compared to prevocalic position (McGowan, Nittrouer, & Manning, 2004; Stoel-Gammon, 1985; Smit, Hand, Freilinger, Bernthal, & Byrd, 1990; Templin, 1957). McLeod, Sutton, Trudeau, and Thordardottir (2011) studied the acquisition of consonants in Quebecois French in pre-school aged children revealing that the consonants acquisition was earlier in the initial position of the word followed by medial position and then final position.

Unlike English, Kannada, a Dravidian language, is a syllabic language (words end with a vowel) and according to its phonotactic rules, there are only two positions, namely, initial and medial positions. So, a sound in Kannada language can be acquired either at initial or medial position. According to phonotactic rules of Kannada, the nasal and lateral retroflex sounds occur only in the medial position whereas, rest of the sounds occur either in the initial or medial position (Upadhyaya, 1972).

Deepa and Savithri (2010) revised the Kannada articulation test and reported the sound acquisition pattern in children in the age range 2-to 6- years. They found that in girls, velars, dentals, bilabials, nasals, and glides were acquired both in the initial and final positions by 2.6 years. On the other hand, in boys, the voiced velars, dentals, and bilabials were acquired in the medial position, whereas, their voiceless cognates were acquired only in the initial position by this age. Nasals and glide /j/ were acquired in both positions by 2.6 years in boys. Affricates were reported to be acquired in both initial and medial positions by 4 years. Retroflex sounds were acquired by 5 years in both phoneme positions. Palatal /ʃ/ was found to be acquired first in the initial position, whereas, dental /s/ in the medial position.

Shishira and Sreedevi (2013) and Sushma and Sreedevi (2013) investigated the phonetic repertoire, syllable structure, and cluster acquisition in typically developing children in the age range 12-to18- months and 18-to 24- months respectively. The combined findings found low-central vowels occurring (medial position followed by initial and then final position) more frequently followed by high-back vowels and then high-front vowels. The vowels [i:] and [o] occurred in the medial and final positions respectively more compared to the initial position. Bilabials and velars were found to occur more in the initial position of the word, whereas, palatals, dentals, and glottal sounds were more in the medial position. Retroflex sounds were found to occur both in the initial and medial positions almost similarly.

The literature on influence of phoneme position highlights its importance in acquisition of speech sounds. The influence is observed as early as in infancy and toddler stages similar to vowel influence.

The facilitatory effect of vowel contexts and phoneme positions are apparent from the literature. Simultaneously, there are also error productions due to certain phonetic contexts during typical speech development, leading to phonological deviations like assimilation, coalescence, cluster reduction and other idiosyncratic productions. Generally such errors diminishe between 3- to 6-years of age. These deviations or phonological processes are due to the phonetic contexts such as phoneme position in a word, neighboring vowels, and consonants etc (Fleming, 1971; Spriestersbach & Curtis, 1951; Snow, 1963). Persistence of such deviations beyond a particular age leads to speech sound disorders.

2.3. Speech Sound Disorder

Speech sound disorders (SSD) is a broader term referring to a combination of intricacy in speech perception, speech-motor production, and/or the phonological representation of speech sounds and speech segments including phonotactic rules of the language and prosody that impact speech intelligibility. The impact can be either on the form of speech sounds resulting in articulation disorders or on the function of speech sounds within a language resulting in phonological disorders.

American Speech and Hearing Association, ASHA (2004b) recommends using speech sound disorder as a cover term, with the articulation/phonology dichotomy and notes that 'Intervention in speech sound disorders addresses articulatory and phonological impairments, associated activity and participation limitations, and context barriers and facilitators by optimizing speech discrimination, speech sound production, and intelligibility in multiple communication contexts' (cited in Bowen, 2015, p. 42). Bernthal, Bankson and Flipsen (2009) also suggest using the term 'speech sound disorder' in clinical setups.

Two major subgroups have been identified in children with SSD (Pascoe, Stackhouse, & Wells, 2006; Shriberg, Tomblin, & McSweeny, 1999):

(1) Poorly unintelligible preschoolers with low percentages of consonants correct (PCCs) and multiple errors and

(2) Acceptably intelligible school-aged students with high PCCs and residual errors.

In clinical settings, the generally used classification system is based on etiology: unknown cause, supposed or putative cause, and known cause (Bowen, 2009). Bowen states that SSD is generally considered to have no identifiable casual factor and is usually given the term 'functional speech disorder'.

Diagnostic and Statistical Manual of Mental Disorders, DSM – V (American Psychiatric Association, 2013) has provided four-criteria for SSD. These include:

1. Persistent unintelligible speech consisting of phoneme addition, omission, distortion or substitution, which interferes with verbal communication
2. There is interference with social participation, academic performance or occupational performance (or any combination of these)
3. Onset of symptoms during childhood
4. The symptoms cannot be accounted for by another medical or neurological condition, including traumatic brain injury.

Many theoretical frameworks like Dodd's diagnostic framework (based on speech characteristics, 1995), Shriberg's classification (physiological basis, Shriberg et al., 2010), and Bowen's classification (based on underlying levels of difficulty, 2011) classify speech sound disorders. Dodd's and Bowen's classifications are described in depth as they are more appropriate for the current study.

I. Dodd’s diagnostic framework (1995) classifies speech disorder into 5 sub-groups based on speech characteristics.

1. Articulation disorder: Presence of substitutions and distortions in any phonetic context on any task.
2. Phonological delay: Presence of speech error patterns those are typical of younger children as determined by normative data.
3. Consistent atypical phonological disorder: Consistent use of one or more unusual nondevelopmental error patterns as determined by normative data.
4. Inconsistent phonological disorder: Multiple phonemic error forms for the same lexical item while having no oro-motor difficulties.
5. Childhood Apraxia of speech (CAS): Speech characterized by an inconsistency, oro-motor signs (e.g., groping, difficulty sequencing articulatory movements) and poorer performance in imitation than spontaneous production.

II. Bowen (2011) classified SSD based on the underlying levels of difficulty as follows:

1. Anatomic /sensory: ankyloglossia, cleft lip palate, hearing impairment
2. Motoric: execution dysarthria, planning apraxia

3. Perceptual: articulation and phonological disorders
4. Phonetic: articulation disorder
5. Phonemic: phonological disorder

2.3.1. Incidence and Prevalence of SSD.

Incidence and prevalence studies report that children with functional SSD encompass the largest sub-group in child speech impairment. It has been found that 7.5% of all children aged between 3-to11- years, experience SSD (of both known and unknown etiology) in United States of America (Shriberg & Kwaitkowski, 1994). In a recent survey, Broomfield and Dodd (2004a) established that 6.4% of all children in the United Kingdom are affected by functional SSD. Research studies on incidence and prevalence report that developmental speech sound disorders are most commonly occurring childhood disorders affecting 10-15% of pre-school children and 6% of school children (McLeod & Harrison, 2009).

A survey by ASHA (2006) found 91% of SLPs working in public schools serving children with SSD. Mullen and Schooling (2010) reported 56% of school-based SLPs serving children with SSD. National Institute on Deafness and Other Communication Disorders, NIDCD (2010) have reported that the prevalence of speech sound disorder is 8-9% in young children. In the same year, Karbasi, Fallah, and Golestan conducted an epidemiological study in Yazd-Iran. They found that the prevalence of speech sound disorder was 13.8% followed by stuttering (1.2%) and voice disorders (0.47%). Also, the prevalence was reported to be more in males (16.7%) as compared to females (12.7%). In another study, Cavalheiro, Brancilioni, and Keske-Soares (2012) found that the prevalence of phonological disorders in children from Salvador, Bahia, Brazil was 9.17% (164/2880 children). The prevalence was found to be more in males (13.3%) compared to females (8.96%). Also, it was found that the middle socio-economic status presented higher prevalence (9.69%) compared to high (9.06%) and low (8.75%) levels. Later Devadiga, Varghese, and Bhat (2014) conducted a retrospective study at Kasturaba Medical College, Mangalore. They reported that overall 14% had speech disorders out of which 48.4% had articulation disorder. Also, they found that the articulation disorder was more prevalent in pediatric population. The recent prevalence report by Jayashree, Arunraj, and Madhusudarshan (2015) revealed 18.6% of the total children surveyed in and around Mysuru, Karnataka, had speech sound disorder. SSD is a significant communication problem in school-aged children (Pena-Brooks & Hegde, 2017). Literature found children with SSD to be at risk for either short-term or long-term difficulties in various domains such as, academics (writing and reading), social and emotional domains, that eventually impacts occupational opportunities in adulthood (Felsenfeld, Broen, & McGue, 1994; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004). Gillon (2004) reports literacy difficulties and phonological deficiencies strongly correlate. Children with severe phonological disorders have recurrently experienced problems in phonological awareness (Gillon, 2004); phonological representation (Nathan, Stackhouse, Goulandris, & Snowling, 2004; Stackhouse, 1997); reading (Bird, Bishop, & Freeman, 1995); and spelling (Clarke-Klein & Hodson, 1995). Also, incorrect production of speech sounds leads to speech unintelligibility posing a robust negative effect on social and emotional aspects as well. Findings of retrospective studies on co-occurring difficulties of SSD noted adults with phonological disorder in childhood having global challenges in retrieval, manipulation, and comprehension of linguistic information (Felsenfeld, Broen, & McGue, 1992; Felsenfeld, McGue, & Broen, 1995; Lewis, Ekelman, & Aram, 1989; Lewis & Freebrain, 1992). Felsenfeld, Broen, and McGue (1994) found 70% of the adults with a history of phonological disorders failed to earn a college degree and also held an unskilled job. These reports suggest a great concern.

Studies on contextual facilitation have also been carried out on children with SSD. The following sections describes the studies on influences of vowels and phoneme positions on the production of speech sounds in children with SSD.

2.3.2. Role of vowel contexts in production of phonemes in children with SSD.

Earlier English literature on vowel effects are confined to late acquiring speech sounds like fricatives, affricates, and trills. Muntyan (1963) considered 53 kindergarten children aged 5-to 6-years with non-organic speech disorder to explore the articulation of fricative /s/ in various phonetic contexts. The 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 mode of response was spontaneous naming. If the response was incorrect, then picture or question cues were provided. The response from participants was elicited until the target was produced correctly. 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/. This they attributed to the acceptable and unacceptable positions of [s] production where there is a significant difference between the relationships of the highest part of the tongue to the palatal arch during the two conditions. The highest part of the tongue during acceptable production was the dorsum rather than the tip and this supported their result reporting that preceding vowel /i/ was least facilitating. On the other hand, Zehel et al. (1972) and Mowrer (1989) 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/.

Hoffman, Schuckers, and Ratusnik (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]. Although this was not true for vowel / æ/, it shared common features (+ long and + front) with /i/. These results they 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.

An extensive study by Elbert and McReynolds (1978) considered five functional articulation disordered preschool or kindergarten children in the age range 5 years 6 months to 6 years 4 months who either inter - dentalized or omitted /s/, to explore the facilitating phonetic context for the production of fricative /s/. The research design used was ABAB (reversal) combined with multiple baselines for better control over the variables. Fricative /s/ was taught in limited number of contexts and explored its generalization to other untrained contexts. They provided a minimum of 30 individual therapy sessions three to four times per week. The training stimuli comprised of non-sense syllable sequences like /sʌ/, /ʌs/, /ʌsʌ/ paired with non-sense pictures black line drawings and in the reversal condition same three non-sense pictures were labeled as /θʌ/, /ʌθ/, /ʌθʌ/ instead of the target fricative. 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.

Shuckers, Mazza, and Daniloff (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 three vowels /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.

Bennet and Ingle (1984) investigated 50 children in the age range of 6-to12- years with functional articulation disorder misarticulating /s/. Results revealed that prevocalic /s/ was least erred in the context of vowel /ʌ/ and highly erred in the context of word initial clusters. This study was partially contradictory to the research by Gallaghar and Shriner (1975a) describing consonant clusters as the most facilitating context for /s/ than consonant vowel context. On similar lines, in the recent past Bauman-Waengler (2012) have established vowel key environments based on clinical observations which are depicted in Table 2.3.

Table 2.3

Compatible and incompatible vowel contexts to teach error sounds (Bauman & Wangler, 2012)

Target sound	**Compatible vowel/sound**	**Reason**	**Incompatible vowel/sound**	**Reason**
[s] and [z]	[i], [ɪ], [ɛ], [e], [æ]	Both the sounds have similar articulatory movements: anterior position of the tongue with lip spread. The authors report that this condition facilitates the establishment of [s] and [z] in a child's repertoire.	[u], [ʊ], [o], [ɔ]	The vowel [u] has a contrast movement of articulators with respect to [s] or [z]: posterior tongue placement and lip rounding which works against the establishment of [s] and [z].
[ʃ] and [ʒ]	[i], [ɪ], [ɛ], [e], [æ]	If the difficulty is with tongue placement, then the authors suggest establishing these sounds in the context of high front vowels.	[u], [ʊ], [o], [ɔ]	The authors report that articulatory movement of [u] contradicts the movement of these sounds if the error is due to the placement of the tongue.
	[u], [ʊ], [o], [ɔ], [ɝ], [ɚ]	If the difficulty is with rounding of lips, then the authors suggest establishing these sounds in the context of high	[i], [ɪ], [ɛ], [e], [æ]	The authors report that, if the error is due to rounding of lips, high front vowels work against

Table 2.3 continued

Target sound	**Compatible vowel/sound**	**Reason**	**Incompatible vowel/sound**	**Reason**
		Back vowels and few central vowels with some degree of lip rounding.		The target.
[k]	[u], [ʊ], [o], [ɔ], [ɑ]	If the child is substituting, front sounds for [k], then the authors suggest using high back vowel to establish the posterior tongue placement for the production of [k].	[i], [ɪ], [ɛ], [e], [æ]	The articulatory movement for [i] would facilitate front tongue placement which has been reported to be against the production of [k]
	[i], [ɪ], [ɛ], [e], [æ]	High front vowel phonetic context has been suggested, if velar sounds are produced postdorsal uvular. The sequence suggested is high-front, mid-front, low-front, central, low-back, mid-back, and high-back vowels		

Table 2.3. continued

Target sound	Compatible vowel/sound	Reason	Incompatible vowel/sound	Reason
[g]	[ŋ]	They suggest that more than vowel context, it's in the context of abutting consonant [ŋ], [g] is established easier. They also suggest to teach [g] following [k].		
[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].
	Back vowels	Recommended in case of [l] distortions as the concave posture of the tongue are believed to support relaxation of the lateral edges. In addition, they also propose that the dark /l/ would be easily established in the word-final position.		
		Believed to facilitate production of dark /l/.		

Table 2.3 continued

Target sound	Compatible vowel/sound	Reason	Incompatible vowel/sound	Reason
		The authors suggest the following 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]. The authors suggest the following sequence of vowels: high-front, mid-front, low-front, central, low-back, mid-back, and high-back vowels.		
[r]	Central vowel without r-coloring [ɑ]	Produced with elevated mandibular position which is believed to support the production of [r]	Front and back vowels	The posterior and anterior positioning of the tongue does not support the production of [r] as stated by the authors.
	Back vowels	Facilitates the production of bunched [r] which involves lip rounding feature as present in production of back vowels.		

Table 2.3 continued

Target sound	Compatible vowel/sound	Reason	Incompatible vowel/sound	Reason
[ð] and [θ]	High-front vowels [i], [ɪ], [ɛ], [e], [æ]	Both the target sound and the vowel need anterior movement of the tongue and hence the establishment of these sounds in the context of high-front vowels has been recommended by the authors. Authors also provide possible 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]	These vowels would need posterior movement of the tongue which is opposite to the movement of tongue required for the production of the target sound. Hence, high-back vowel context is not proposed to establish the production of these target sounds.
[f] and [v]	High-front vowels [i], [ɪ], [ɛ], [e], [æ] and central vowel [ɑ]	Authors provide possible 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 of these vowels has been proposed to be unfavorable for the establishment of [f].
[ʧ] and [ʤ]	High-front vowels [i], [ɪ], [ɛ], [e], [æ]	High-front vowels have been suggested to provide support for the production of affricates, as the feature, anterior tongue placement is common for both, and hence, facilitates the		

Table 2.3 continued

Target sound	Compatible vowel/sound	Reason	Incompatible vowel/sound	Reason
		production of affricates. The authors suggest the vowel sequence under this circumstance is: high to low front vowels followed by central and then back vowels.		
	High-back vowels [u], [ʊ], [o], [ɔ]	The authors also report that there are two advantages of working on affricates in the context of back vowels: (1) lip rounding of high-back vowels might provide articulatory support for the production of [ʧ] (this affricate also has lip rounding feature), (2) posterior movement of the tongue during the production of back vowels may enhance the backward gliding movement of the tongue during the transition from stop to fricative portion of the affricate.		

Table 2.3 continued

Target sound	Compatible vowel/sound	Reason	Incompatible vowel/sound	Reason
		The vowel sequence under this circumstance has been proposed to be high to low back vowels followed by central and then front vowels.		

Facilitatory effects of vowel context have been explored in the Indian context by a couple of researchers. Krishna and Manjula (1991) studied a 15 year old participant with misarticulation of retroflex /ʈ/. The intervention involved a hierarchy of steps: auditory training and discrimination tasks followed by multisensory with phonetic placement approach in isolation followed by production of target in various contexts at non-word and then word level. Pre-therapy and post therapy comparison was carried out using acoustic analysis. The production of retroflex / ʈ / was found to be facilitated more in the context of vowels /a/ and /i/ compared to /u/, /e/ and /o/.

2.3.3. Role of phoneme positions in production of phonemes in children with SSD.

Scott and Milisen (1954) found that the phonemes /f, z, s, k, l, v, r, g/ were produced correctly more in the initial or final positions of a word than in the medial position in children with articulation problems in the age range 4-to14- years. Also, they reported that the production of /s/ was more accurate in the context of clusters (/st, sn, sp, sk/) than in the context of vowel (CV).

Similar study has been carried out on the liquid /r/. Curtis and Hardy (1959) considered 30 children with functional misarticulation in the age range 5.6-to 8.6-months. Word elicitation task was carried out using picture cards. They found that the phoneme /r/ was articulated more correctly in consonant blends (especially front-stop consonant blends) than in singletons. They also found that the intersyllabic /r/was produced more correctly compared to /r/ in the initial or final position. Studies have found that 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 (Eisenson & Ogilive, 1977).

Haynes, Haynes, and Jackson (1982) found no position effect on the production of fricatives /s/ and /z/ as reported by Gallagher and Shriner (1975a). On the other hand, Rockman and Elbert (1984) investigated the untrained acquisition of fricative /s/ in child with phonological disorder and found that the acquisition pattern of speech sound /s/ was in similar pattern as observed in typically developing children where fricative /s/ is acquired in the final position followed by initial and then in the medial position.

Later, Ghandour and Kaddah (2011) studied factors affecting stimulability of errored sounds in common types of dyslalia. They applied stimulability test for the erred phonemes in isolation and syllables on 75 Arabic speaking children. They were equally divided into three groups: Group 1 – sigmatism, Group 2-front-to-back displacement, and Group 3-rhotatism. They found that stigmatism group was highly stimulable followed by front-to-back displacement group and then rhotatism group. They attributed this to the fact that airstream of fricatives are partly blocked and hence, can be produced in isolation which makes children to identify them as separate units. On the other hand, stops are produced with the complete obstruction of airflow and hence, difficult to identify them as separate entities. The results were also attributed to acoustic studies which state that the following phoneme have an effect on the acoustic representation of stops to a large extent (Treiman, Broderick, Tincoff, & Rodriguez, 1998) meanwhile, the acoustic representation is constant across the context in case of fricatives (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967). Voiceless phonemes were more stimulable compared to voiced counterparts. In terms of phoneme position, results revealed highest stimulability in the initial position followed by medial position and then final position. This they attributed to the fact that stimulable children had higher correct positions in the initial position.

An observation was made during a study by Shalini and Sreedevi (2016) on the efficacy of non-words in articulation therapy for the trill /r/ and the fricative /ʃ/. They observed that the production of trill /r/ was facilitated in the medial position compared to the initial position even in non-words.

2.3.4. Facilitatory effect of vowel contexts and phoneme positions on the production of phonemes in children with other communication disorders (Hearing Impairment)

Effect of vowel contexts and phoneme positions on production of speech sounds have been studied in children with hearing impairment as well in the Indian context. However, there are sparse studies on population with different communication disorders in both Western and Indian context. Anu Rose (2017) investigated the facilitatory vowel context for the correct production of velars /k/ and /g/ in 6 native Malayalam children with hearing impairment using pre-post therapy comparison. The stimuli comprised of bi-syllabic non-words (vowel harmonized and non-harmonized). The task involved participants to repeat the stimuli words and upon incorrect production, phonetic placement approach was used to teach the place of articulation of the target. The results revealed that vowel /a/ was the highly facilitating context for the correct production of velars in children with hearing impairment and was attributed to the physiological fact that vowel /a/ is least coarticulatory resistant with velars (Irfana, 2017). Similarly, Merin (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 3-7 years with severe to profound hearing loss with misarticulations of affricates and fricatives were intervened. Non-words in consonant harmonized and consonant non-harmonized conditions were used as stimuli. Percentage of correct consonants pre- and post-intervention served as the measure. Results revealed that production of fricatives, /s/ and /ʃ/ are 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. However, authors suggested that it is vital to validate results in this regard.

2.3.5. Establishment of key enviroments on the production of phonemes in children with SSD – Clinical observations.

Bleile (1991, 1996, 2006, 2015) in series of clinical observations has established key environments facilitating the production of various English phonemes. Bleile (2015) prefers key environment utilization for articulation therapy in children, typically under 4-to 5-years of age, with speech sound disorders. Bleile (1996) describes facilitative phoneme positions and vowel contexts for the production of various phonemes. The key vowel environments are depicted in Table 2.4.

Table 2.4

Facilitative environment for successful production of a sound class in English (Bleile, 1996)

Treatment targets	Facilitative environments	Example
Nasal consonants	Before a low vowel	***Ma**d*
Alveolar consonants	Beginning of words before front vowels in the same syllable	***Te**a*
Velar stops	End of word	*Pea**k***
	Beginning of words before a back vowel in the same syllable	***Go***

Similarly, Bleile (2006) provided facilitative contexts for late acquiring sounds in typically developing children (Table 2.5).

Table 2.5

Facilitative environment for late acquiring sounds in English (Bleile, 2006)

Treatment targets	Facilitative environments	Example
/θ/	End of a syllable or word	*Tee**th***
	Before high front vowel	***Th**in*
/ð/	Between vowels	*Wea**th**er*
	Before high front vowel	***Th**ese*

Table 2.5. continued…

/s/	End of a syllable or a word	*Bu**s***
	Before high front vowel	***S**ee*
/z/	End of a syllable or a word	*Fi**zz***
	Before high front vowel	***Z**ip*
	After [d] and before [i]	*D**z**i*
	After [d] occurring in the same syllable	*Bead**s***
/l/	Light /l/: Before high front vowel	***L**eaf*
	Dark /l/: after a high back vowel at the end of a syllable	*Ca**ll***
Vocalic /r/	Word consisting single stressed syllable	*Gi**r**l*
Consonantal /r/	Before high front vowel	***R**id*
	Between vowels	
	Syllable initial consonant velar cluster	*C**r**eek*
/ʃ/	End of syllable or word	*Fi**sh***
	Before high front vowel	***Sh**e*
/ʧ/	End of syllable or word	*Ba**tch***
	After high front vowel	*Wi**tch***

Recently, Bleile (2015) categorized 12 key environments into three groups and the details are given in Table 2.6.

Table 2.6

12 key environments (Bleile 2015)

	Targets	Key environments	Examples
Consonant classes	Voiced consonants	Before or between vowels	Bee and driver
	Voiceless consonants	At the end of syllables or words	Bit
	Alveolar consonants	Before /i/	Tea
	Velar consonants	At the end of a syllable or word, or next to /u/ in the same syllable	Peak and luke
Individual consonants	[k]	Syllable final position after [u]	Duke
	[ʃ]	Next to [u]	Bush and shoo
	[s]	Before [i] or in consonant cluster containing [t]	Steep and pots
	[l]	Before [i]	Leaf
	[r]	Before [i] or in consonant cluster	Read, greet, tree, and dream
Other facilitative contexts	[h] facilitates production of word-initial vowels without hard glottal stop		Eat as heat
	In two-word phrases, a word-initial vowel of the second word facilitates migration of the preceding word-final consonant into word-initial position		It is as I tis
	The word initial and final consonants having same place of articulation facilitates closing a syllable with consonant		King and beep

The above literature signifies the definite effect of vowel contexts and phoneme positions on the production of speech sounds. Consideration of such phonetic contexts in assessment and intervention will certainly help in preserving cost and time by guiding the SLPs appropriately.

2.4. Contextual based assessment of SSD

An appropriate detailed assessment is the key to good intervention. Generally speech-language pathologists collect information from the participants using two procedures. They initially screen the children for speech sound disorder. Later, a comprehensive evaluation is carried out. Bernthal, Bankson, and Flipsen (2009) suggest that a comprehensive phonetic-phonemic evaluation forms the core or base for the intervention of articulatory/phonological disorders. According to them, the comprehensive evaluation includes data from the following sources:

1. A standardized articulation test
2. Conversational speech assessment in varying contexts
3. Hearing evaluation
4. Speech mechanism examination
5. Additional measures such as language assessment, intelligibility assessment, perceptual evaluation, cognitive assessment, and contextual testing.

The data collected during assessment are transcribed using International Phonetic Alphabet (IPA) and analyzed. The analysis can be carried out in the following ways:

1. SODA errors (Substitution, omission, deletion, and addition)
2. PVM Analysis- Place, Voive and Manner Analysis
3. Distinctive feature Analysis
4. Phonological process Analysis
5. Contextual based analysis

Generally, it is noted that contextual based analysis is ignored compared to other types of analysis as there are no tests which assess a speech sound in all the phoneme contexts and positions. The Deep Test of Articulation by McDonald (1964a) in English, Secord Contextual Articulation Test (Secord & Shine, 1997), the Deep test of articulation in Kannada-Sentence form (Rohini & Savithri, 1989; vowel environment), the Deep test of articulation in Malayalam- Sentence form (Maya & Savithri, 1990; vowel environment), the Deep test of articulation in Hindi – Picture form (Deepa Shankar & Savithri, 1998; consonant environment), the Deep test of articulation in Bengali – Picture form (Animesh & Savithri, 1991; consonant environment), the Deep test of articulation in Nepali – Picture form (Bhavani & Savithri, 1995; consonant environment), and the Deep test of articulation in Tamil – Picture form (Sangeetha & Savithri, 1995; consonant environment) assist clinicians in analyzing such key phonetic contexts/key environments. These test materials assesses various speech sounds in different vowel context, phoneme positions, and cluster contexts. Ghandour and Kaddah (2011) state that determining the most stimulable sound and the phoneme position in which a phoneme is easily stimulable is crucial in the treatment plan.

In sum, a comprehensive analysis of speech sound errors provides an appropriate base for selecting the targets and the key environments for intervening children with speech sound disorders. Hence, contextual based analysis should serve as the core of a comprehensive analysis for assessment and intervention of SSD.

2.5. Contextual based intervention of SSD

A major part of the intervention of speech sound disorder is the selection of target phonemes. To choose a target or an intervention approach there is no simple universal prescription as the client values and clinical expertise vary. Generally, the phonemes which are either not acquired according to age or those that are produced incorrectly are considered as target phonemes for the intervention.

In the intervention process, the target phonemes are taught initially at the syllable level or at the word level. Hence, it becomes important to consider the vowel context and the phoneme position, the target phonemes are taught. Literature suggests that phonetic environment (Curtis and Hardy, 1959; House, 1981; Kent, 1982) and the phoneme position (Bernthal and Bankson, 1981; Spriestersbach and Curtis, 1951) are among the variables that affect articulatory productions. It has been observed that coarticulatory aspects can be used to establish speech sounds in a child's repertoire. The phonetic context becomes very important clinically. Kent (1982) reasons it out first with regard to assessment by suggesting that the speech-language pathologists might get different results from different tests depending on whether the stimuli uses highly facilitative contexts or highly non-facilitative contexts. Generally, it is observed that very limited contexts are tested in standard articulation tests or informal screening tests. Another reason what the author provides is related to intervention. The intervention decisions may be based on the context sensitivity for correct sound production, that is, the intervention would proceed from highly facilitative contexts to less facilitative and then non-facilitative contexts. According to some theories of coarticulation (Kozhenikov and Chistovich, 1966; Henke, 1966), any portion of the tongue not involved in the articulation of a consonant, is free to assume a position for a segmental target. Swisher (1973) provides two physiologic reasoning for particular context facilitating a particular speech sound. First, the context is minimally interfering or competing with the error sound and thus, facilitating. Swisher provides with an example, that the context of /p/ is more facilitating for the production of /s/ as the bilabial /p/ reduces the burden on the tongue and also shares only two features in common, that is velopharyngeal closure and voicelessness with /s/. Another reason is the similarity between the error sound and the phonetic neighbor. The data indicated that /s/ production is facilitated in the word-initial cluster with a phonetic neighbor that is similar in features with it (/st/). Another example is, correct production of /i/ and /u/ requires close palatal or velar approximations in the vocal tract. Such anticipatory or right to left (R-L) coarticulation involving movement of the tongue towards these vowels during /r/ production (Daniloff & Hammarberg, 1973) may be facilitative as movements toward these positions are in close proximity to the target for [r].This is also supported by the physiological reasoning by Gallagher and Shriner (1975b) stating that “Large articulatory adjustments seem to place more constraints on the speech production mechanism, and correspondingly, the chance error for segments within the motoric unit is increased” (p. 631).

Frame-Content theory (Davis & MacNeilage, 2004) describes about the key environments for the production of speech sounds. This theory supports the fact that one sound has an effect on the other. Also, provides a base for the key environments that expedite the speech sound production and intelligibility gains. On similar lines, Bleile (1991b, 1996, and 2006) and Bauman-Wangler (2012) have provided key environments based on their clinical observations, for establishing a speech sound in a child’s repertoire that supports the view of Davis and MacNeilage. They also suggest replication of such clinical observations to validate the results.

Literature also highlights on studies applying the knowledge of facilitating vowel contexts and phoneme positions in selecting the stimuli for SSD intervention.A single subject design was carried out with one participant by Stringfellow and McLeod (1994). They considered a 5 year old child who was consistently substituting /l/ for /j/. The child was diagnosed to have delayed receptive and expressive language also at the age of 3.8 years. Minimal pair approach and traditional articulatory approach were carried out to teach production of the glide /j/ between the ages 3.8-to5- years but did not prove to be effective. So, the researchers used a key word having two facilitating vowels (the vowels which make up the glide /j/: [i] and [a]) for the production of glide /j/. The key word used was [ija] which is the Australian pronunciation of ‘Eeyore’ the name of a cartoon character. The child was made to gradually glide the tongue from [i] to [a] while producing [ija]. Later, the word was segmented into [i] and [ja]. The gap between [i] and [ja] were either filled silence or by prolonging the vowel [i]. Gradually the duration of the gap was increased until the child was able to produce [ja]. Then the child was made to realize that /l/ and /j/ are two different phonemes. By fifth session the child was able to use the glide /j/ in naturalistic carrier phrases.

Stokes and Griffiths (2010) investigated the effects of facilitative vowel contexts in establishing consonant production in a 7 year old boy with post-alveolar fronting. The target speech sound considered was fricative [ʃ]. The treatment was carried out in four stages. Initially, the target sound was taught using VC or CVC non-words in the context of back vowels and in the final position of a word (eg. [ɔʃ] and [mʊʃ]). This was attributed to the fact that the back vowels and word final position are facilitating for the production of fricative [ʃ]. In the second stage, the target sound was to be produced in CVC word+ CVC non-word combination in the word final position. In the third stage, the production of target sound was practiced in the context of minimally facilitative vowel context in CVC structure (eg. [mɪʃ], [pɛʃ]) and in the medial position (eg., [mɪʃa]). Finally, in the fourth stage the production of the target sound was practiced in the word initial position. They reported that targeting the facilitating vowel context did prove to be effective in establishing the correct motor programme for post-alveolar fricative in the child with phonetic disorder and not phonological. Also, they highlighted that selection of vowel context is tailor-made to suit the child's needs and generalization to other sounds is unlikely to happen rather generalization across segments that share same place of articulation might occur.

These studies prove the significance of selecting proper phonetic contexts in intervening different target phonemes for speedy speech correction. This indicates that establishing facilitating phonetic contexts for various speech sounds in different languages is essential.

Contextual utilization approaches has been advocated by some clinical phonologists (Hoffman, Schuckers, & Daniloff, 1989; McDonald, 1964a). The rationale behind these approaches is that speech sounds are produced in syllable-based contexts and not in isolation. McDonald suggested that the articulatory errors be started in those contexts where the error sound can be produced correctly. The following steps have been proposed by McDonald with example of /s/ production:

1. Identify the context in which the error sound is produced correctly (/s/ is produced correctly in the context of ‘watchsun’)
2. Say the target word in slow motion
3. Say the target with equal stress on both syllables
4. Then say with primary stress on first syllable
5. Then say second syllable with primary stress
6. Say watchs and prolong [s] until it is indicated to complete bisyllable
7. Say short sentences with the same context (Watch, sun will burn you)
8. Practice various sound combinations with different rates and stress patterns and later practiced at sentence level.

Hoffman, Schuckers, and Daniloff (1989) provided another variation to the contextual approach with a basic assumption that “revision of over learned, highly automatic behavior is possible though carefully planned and executed performance rehearsal” (p.248). The steps are as follows:

1. Stimulability tasks where in the SLPs model the correct production of error sounds
2. Learning the articulatory adjustments necessary for correct target sound production
3. Rehearsal-has four levels of complexity:
    a) *Nonsymbolic units*: Here the target productions are practiced in VC, CV, VCV, and VCCV nonsense syllables.
    b) *Word and word-pair practice:* Here there is a transition from non-sense syllables to words. They are designed to encourage the child to assume

responsibility for identifying and judging the adequacy of his or her performance.

c) *Rehearsal sentences*: Repetition of modeled sentences that include words practiced in the previous level/stage.

d) *Narratives*: Target sound to be practiced is embedded in communicative tasks.

Phonemic approaches also use the concept of contextual facilitation. Paired stimuli approach (Irwin & Weston, 1971) uses key words involving facilitating contexts. This uses operant principles in a behavioral reinforcement paradigm to facilitate generalization from one context to others. Contextual facilitation is the vital procedure in implementing paired stimuli approach which supports generalization of production of target phonemes from facilitative to other contexts. Irwin reported data for 388 children treated with this technique; average of 83 min of intervention; 80% correct response in a non-contingent single-word probe condition.According to Cycles approach (Hodson & Paden, 1983), phonological learning is facilitated through the development of new auditory and kinesthetic images occurring during production practice of target phonemes in facilitating contexts at word-level using drill-play format. These approaches are in clinical use and has proven fruitful in speech correction of children with SSD.

Literature review on contextual effects emphasize on their definite influence on production of speech sounds. However, most of the Western studies on contextual have fewer sample size, confining to only few phonemes, not extensive and not intervention based. On the other hand, few studies are extensive on only few target phonemes using single subject designs (Elbert & McReynolds, 1975, 1978) but focused on studying contextual influence during generalization phase on untrained stimuli. The key environments for various speech sounds established by Bleile (1991, 1996, 2006, 2015) and Bauman-Waengler (2012) are solely based on clinical observations and they have recommended validation of their findings by replicating such studies. Generally these Western studies are confined to late acquiring sounds. Velars, retroflex, trill, fricatives, and affricates (Appendix 1) are frequently erred sounds in Kannada and these are seldom addressed in such context-based studies. There are only few Indian studies targeting children with communication disorders on these lines and have focused on limited number of speech sounds. The influence of vowel contexts and phoneme positions on other cognates of retroflex (voiced, nasal and lateral), velars, affricates, and fricatives in Kannada are not established. Studies on typical speech development focus on speech production and not on contextual facilitation directly. As coarticulation is language specific, the findings of one language cannot be applied to another indicating the importance to carry out such studies in various languages. Indian research in this regard is still in its nascent stage and replication of earlier studies is necessary to validate the findings and apply it clinically considering the high prevalence of SSDs. To bridge these gaps in research and from a clinical point of view to provide guidelines for SLPs to prepare appropriate stimuli for effective speech invervention, the present study aimed at establishing the facilitating vowel contexts and phoneme positions for the correct production of errored phonemes in children with SSD.

Chapter 3: Method

The present study aimed to establish the contextual effect of vowels and phoneme positions on the production of speech sounds in children with SSD through articulatory intervention. The main objectives were:

1. To study the contextual influence of vowels /a/, /i/, and /u/, following the target phoneme at word level on the production of speech sounds in native Kannada speaking children with SSD through articulatory intervention.
2. To investigate the contextual effect of phoneme positions (initial and medial) at word level on the production of speech sounds in native Kannada speaking children with SSD using through articulatory intervention.

The hypotheses made are as follows:

1. There will be no contextual effect of vowels /a/, /i/, and /u/ on the production of speech sounds in children with SSD through articulatory intervention.
2. There will be no effect of phoneme positions (initial or medial) on the production of speech sounds in children with SSD through articulatory intervention.

With this prelude, the present study was carried out in two phases:

1. Phase 1: Establishing the facilitatory vowel and phoneme position contexts for frequently erred speech sounds
2. Phase 2: Validation of Phase 1 results

3.1. Phase 1: Establishing the facilitatory vowel and phoneme position contexts for frequently erred speech sounds

Case study method was employed to test the hypotheses of the current study. Phase 1 of the study is explained in the following section.

3.1.1. Participants.

A total of 27 participants in the age range of 4- to 6-years diagnosed with speech sound disorder at the Department of Clinical Services, at the All India Institute of Speech and Hearing, Mysuru, were assessed for articulatory and other communication abilities in order to confirm their eligibility for participating in the present study as per the inclusion criteria.

Inclusion criteria.

1. Phonetic type of speech sound disorder (Bowen's classification, 2015; Porter, 2015, DSM-V) or articulation disorder (Dodd's classification, 1995) i.e. no motor production of the target phonemes
2. No history of prenatal, natal or post-natal risks
3. No history of delay in speech and language developmental milestones
4. No hearing, language, motor, oro-motor, or any cognitive impairments, ensured using WHO ten disability screening checklist (Malhi & Singhi, 2002) (Appendix 3). Language age assessed by administering the extended version of Receptive-Expressive Emergent Language Scale – REELS (Bzoch & League, 1971), i.e., Receptive-Expressive Language Test (RELT)

5. Absense of central auditory processing disorder was confirmed by administering ‘Screening for central auditory processing disorder, SCAP’ (Yathiraj & Mascarenhas, 2003) (Appendix 4)
6. Native speakers of Mysuru dialect of Kannada and successive early bilinguals with English exposure at school
7. Belongs to middle socio-economic class based on Kuppuswamy Scale of Socio-Economic Status - Updated (Kishore, Kohli, & Kumar, 2015)
8. Parents with minimum education qualification up to SSLC
9. Not enrolled for articulation therapy earlier

The articulatory abilities, for inclusion criterion 1, were assessed using Kannada Diagnostic Picture Articulation Test, KDPAT (Deepa & Savithri, 2010) and errors were documented. Eight of the 27 participants with phonological errors and language issues were excluded from the study. Nineteen participants who met the inclusion criteria were enrolled for further articulatory evaluations and management. However due to attrition only 15 participants (mean age: 4.69 years) out of 19 participated in further evaluations and intervention sessions.

The overall severity of articulatory problem of these 15 participants were calculated using the Percentage Consonants Correct - Revised (PCC-R, Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997) (Appendix 5) for 40 stimuli words targeting only consonants from KDPAT-Part A using the formula:

$$\frac{\text{Total number of consonants correct}}{\text{Total number of targets}} \times 100$$

Each participant's profile on demographic details, speech intelligibility (Appendix 5), articulatory error type (e.g. Appendix 6), error consistency, severity of the problem, intra- and inter-discrimination abilities are provided in Table 3.1.

Ethical board of All India Institute of Speech and Hearing, Mysuru, approved the study and accordingly followed the ethical guidelines by Basavaraj and Venkatesan (2009). A written consent was obtained from parents of all the 15 participants before commencing further assessment and intervention procedures.

Table 3.1

Assessment findings across the participants

Sl. No. and Participants		Age (years) /Gender	Type of errors (with respect to the target phonemes considered for the study)	Consistency	Intelligibility rating (Bowen 2009)	Inter-discrimination	Intra-discrimination	Severity (PCC-R)
1	SJe	5 years/M	Substitution of alveolars for retroflex – fronting errors t/ʈ, d/ɖ, n/ɳ and l/ɭ-in both initial and medial positions and in all the three vowel contexts /a/, /i/, and /u/	Consistent	3- somewhat intelligible in conversation	Good	Good	Mild (88.46%)
2	SH	4.8 years/F	Substitution errors- fronting errors t/k, t/g, t/ʈ, d/ɖ, n/ɳ and l/ɭ-in both initial and medial positions and in all the three vowel contexts /a/, /i/, and /u/	Consistent	3- somewhat intelligible in conversation	Good	Good	Mild (88.46%)
3	SN	5.10 years /F	Substitution errors – fronting errors- n/ɳ and l/ɭ in medial position and in all the three vowel contexts	Consistent	3- somewhat intelligible in conversation	Good	Fair	Mild (90.38%)
4	SB	4.2 years/F	Substitution errors – fronting errors t/k, t/g, t/ʈ, d/ɖ, n/ɳ and l/ɭ-in both initial and medial positions and in all the three vowel contexts /a/, /i/, and /u/	Consistent	4- mostly unintelligible in conversation	Good	Poor	Mild to moderate (71.15%)
5	SHG	5.2 years /M	Substitution errors – fronting errors – t/ʧ in both initial and medial positions and n/ɳ in medial position and in all the three vowel contexts	Consistent	3- somewhat intelligible in conversation	Good	Poor	Mild to moderate (71.15%)
6	ST	4 years/M	t/k, t/g, t/ʧ, and d/ʤ- Substitution errors–fronting errors in both initial and medial positions and in all the three vowel contexts /a/, /i/, and	Consistent	4- mostly unintelligible in conversation	Fair	Poor	Moderately severe (59.61%)

			/u/, but omissions of these phonemes present in the medial position of the words in all vowel contexts.						
7	SHV	4 years/M	Substitution errors – fronting errors - n/ɳ in medial position and in all the three vowel contexts /a/, /i/, and /u/; assimilations observed.	Consistent substitution of n/ɳ and l/ɭ.	3- somewhat intelligible in conversation	Good	Poor	Mild to moderate (84.61%)
8	SJY	4 years/M	Substitution of nasal retroflex n/ɳ in all the three vowel contexts /a/, /i/, and /u/.	Consistent	4- mostly unintelligible in conversation	Good	Poor	Mild to moderate (76.92%)
9	STG	4.3 years /M	Substitution errors – fronting errors- t/k and t/s.	Consistent	3- somewhat intelligible in conversation	Good	Poor	Mild to moderate (76.92%)
10	SR	4.1 years /M	Predominant substitutions of t/ʈ, t/ɖ, n/ɳ, and t/ʤ in both initial and medial positions in all the three vowel contexts /a/, /i/, and /u/; sometimes omissions of these phonemes observed in the medial position; voicing errors.	Inconsistent with respect to substitution or omission	4- mostly unintelligible in conversation	Good	Good	Mild to moderate (71.15%)
11	SS	5.2 years /F	Substitution errors – fronting errors- t/s and d/ʤ in both initial and medial positions and in all the three vowel contexts /a/, /i/, and /u/.	Consistent	3- somewhat intelligible in conversation	Good	Good	Mild to moderate (73.07%)
12	SSA	5 years/M	Substitution errors – fronting errors- t/s in both initial and medial positions and in all the three vowel contexts /a/, /i/, and /u/.	Consistent	2- mostly intelligible in conversation	Good	Good	Mild (86.53%)
13	SG	5 years/M	Substitution errors – fronting errors- t/k and d/g in both initial and medial	Consistent	2- mostly intelligible in conversation	Good	Good	Mild (92.30%)

			positions and in all the three vowel contexts /a/, /i/, and /u/.					
14	SU	6 years/M	Substitution errors-fronting errors- t/k in both initial and medial positions and in all the three vowel contexts /a/, /i/, and /u/.	Consistent	2- mostly intelligible in conversation	Good	Good	Mild (88.46%)
15	SJ	4.5 years /M	t/ʈ, t/ɖ, and n/ɳ substitution or omission in both initial (Not applicable for nasal retroflex) and medial positions and in all the three vowel contexts /a/, /i/, and /u/ Voicing errors; assimilatory errors.	Inconsistent with respect to substitutions and omissions	4- mostly unintelligible in conversation	Good	Good	Mild to moderate (82.69%)

3.1.2. Stimuli.

The target phonemes in each participant were decided based on

1. The age of acquisition as per Kannada Diagnostic Picture Articulation Test (Deepa & Savithri, 2010), and

2. Frequently errored sounds in Kannada as per clinical observations

The final target phonemes considered were stops: velars (unvoiced /k/ and voiced /g/), retroflex (unvoiced /ʈ/, voiced /ɖ/, nasal /ɳ/, and lateral-retroflex /ɭ/), affricates (unvoiced /ʧ/and voiced /ʤ/), and fricatives (unvoiced /s/). The target phonemes and number of targets differed across participants as presented in Table 3.1.

Wordlists for each target phoneme was prepared which constituted commonly used Kannada and English loan-words from daily conversations, Kannada textbooks of primary grades, and dictionaries. Words included the target phoneme in the initial or medial positions in the context of vowels /a, i, u/ following it (eg. /***CV***CV/ and /CV***CV***/). Three speech-language pathologists rated the wordlists for familiarity on a 3-point rating scale as least familiar/familiar/highly familiar. The words rated as familiar and highly familiar by at least two SLPs out of three served as the stimuli. Similarly, the selected pictures of stimuli words were rated for clarity and iconicity using a 2-point rating scale as good or poor and for familiarity using a 3-point rating scale. Pictures rated as either highly familiar or familiar with good clarity and iconicity by at least two out of three SLPs were considered and presented with orthographic forms using MS Power-Point for every target sound.

Finally, the total number of stimuli for /k, g, ʈ, s, ʤ/ were 18 each. This included 3 words each in the context of vowels /a, i, u/ with target sounds in the initial and medial positions constituting 18 words ([3x3] x 2). Target /ɖ/ had 16 words and /ʧ/-17 in possible phonetic contexts as described earlier. According to the phonotactics of Kannada, nasal and lateral retroflex occur in medial positions only and therefore the number of stimuli for /ɳ/ and /ɭ/ were 07 and 09 respectively. On these lines, two separate wordlists, one for intervention and the other for continuous assessment, were prepared for each target phoneme. The wordlists are provided in Appendix 9.

3.1.3. Procedure.

Pilot Study

The applicability of the current procedure was verified by conducting a pilot study on four participants with a mean age of 4 years. Participants assessed for articulatory abilities using Kannada Diagnostic-Picture Articulation Test, KD-PAT (Deepa & Savithri, 2010) and the Deep test of articulation Kannada- Sentence form (Rohini & Savithri, 1989). Following the assessment, the articulatory intervention involved participants repeating target words presented in five random orders. Repeating five orders of wordlists was too tedious for the participants, and thus, three orders of presentation are retained in the main study.

Main Study

The main study composed of pre-intervention stage (evaluation of the dependent variable, i.e., producing the target sound) followed by intervention stage (introduction of the independent variable- phonetic contexts) and then post-intervention stage. Each stage has been explained in detail in the following section.

3.1.3.1. Pre-intervention Phase.

The articulatory assessment was carried out at three data points B1, B2, and B3 to ensure consistency in error production of the target phonemes:

a) B1 – at the first evaluation (conducted to ensure their eligibility as participants for the present study)
b) B2 – one week after the first evaluation
c) B3 – two weeks after the first evaluation. Correct production at B3 served as the baseline for the study

Articulatory assessment involved administering Kannada Diagnostic Picture Articulation Test, KDPAT and Deep Test of Articulation Kannada- Sentence form. The Deep Test of Articulation Kannada- Sentence form was administered only for the error sounds (documented as per assessment results of KDPAT-Part A) to document the facilitating vowel and phoneme position contexts. Participants were made to repeat only the target words from the test sentences in the Deep Test of Articulation Kannada-Sentence form after the investigator, a native Kannada speaker with typical speech and language skills. Two opportunities were provided to produce each test item correctly. A score of ‘1' was given for perceptually correct production and ‘0' for perceptually incorrect production.

The number of stimuli for a target phoneme differed across the phonetic contexts (Appendix 7). Hence, for statistical purposes the number of stimuli were equalized across the phonetic contexts by including words from KDPAT and Deep Test of Articulation Kannada- Sentence form. So, the final assessment list comprised of 12 words each for the following phonemes, /k, g, ʈ, ɖ, ʧ, ʤ, s/ ((3 vowel contexts x 2 positions) x 2 words). And 6 stimuli words for nasal and lateral retroflex ((3 vowel contexts x 1 position) x 2 words). The assessment wordlist is provided in Appendix 8.

Percentage correct consonants - Revised (PCC-R, Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997) was calculated for these stimuli during each pre-intervention evaluation and B3 was considered as the baseline for the intervention. Following B3, articulatory intervention was initiated.

3.1.3.2. Intervention Stage.

Each participant was enrolled for two to three articulation therapy sessions of 45 minutes duration per week. The total number of intervention and continuous assessment sessions across participants varied from approximately 4-to 23-sessions depending on the individual learning pace (Appendix 11). The order of target phonemes for intervention was considered on the fact that unvoiced sounds are acquired earlier to voiced counterparts (Bowen, 2011) and also based on the typical phonological developmental reports in Kannada by Deepa and Savithri (2010). Table 3.2 provides order of target phonemes for each participant.

Table 3.2

Order of target phonemes considered during intervention

Sl. No.	Participant codes	Order of target phonemes
1.	**SJe**	/ʈ/, /ɖ/, /ɳ/, /ɭ/
2.	**SH**	/k/, /g/, /ʈ/, /ɖ/, /ɳ/,
3.	**SN**	/ɳ/, /ɭ/
4.	**SB**	/k/, /g/, /ʈ/, /ɖ/, /ɳ/
5.	**SHG**	/ɳ/, /ʧ/
6.	**ST**	/k/, /g/, /ʧ/, /ʤ/
7.	**SHV**	/ɳ/
8.	**SJY**	/ɳ/
9.	**STG**	/k/, /s/

Table 3.2. Continued…

10.	**SR**	/ʈ/, /ɖ/, /ɭ/, /ʤ/
11.	**SS**	/ʤ/, /s/
12.	**SSA**	/s/
13.	**SG**	/k/, /g/
14.	**SU**	/k/
15.	**SJ**	/ʈ/, /ɖ/, /ɳ/

One or two target phonemes were intervened in a session, and the procedure is as follows:

1. Presentation of picture stimuli words through laptop Acer Aspire 5738G.
2. Wordlist was presented three times in random order (e.g. Appendix 10). However, the response from the first order of presentation was considered for scoring.
3. Participants repeated the stimuli presented. On an incorrect response, phonetic placement approach was used at the word level. A maximum of five chances were provided to learn the target phoneme in a particular phonetic context per session, and only the first production of the target word was considered for scoring. Social reinforcements (verbal praising, pat, etc.) and tangible reinforcements (cartoon stickers) were provided to motivate the child for active participation.
4. Number of correct responses (NCR) scores served as one of the dependent variable and was documented for each vowel context and phoneme position.

Also, the minimum number of intervention sessions to achieve correct production for three consecutive sessions served as another dependent variable.

5. Internal validity was ensured through continuous assessment of target sound production using a different wordlist (matched to the main wordlist based on the number of syllables) on every 4th session, and this also ruled out practice effect.

3.1.3.2.1. Measurement of Dependent Variable 1 (Number of correct responses, NCR).

Each context comprised of three words and the number of correct responses were documented. NCR scores were accounted for each target phoneme across all the vowel contexts and phoneme positions for every session.

3.1.3.2.2. Measurement of Dependent Variable 2 (Minimum number of intervention sessions).

Minimum number of sessions required in each context to achieve 2 correct productions out of 3 repetitions (2/3) or 3 on 3 correct repetitions (3/3) of the target phoneme consistently for three consecutive sessions was obtained through visual analysis of the graphs of NCR scores. Further, these data were subjected to non-parametric statistical analysis.

3.1.3.2.3. Criteria for termination of intervention.

The criterion to shift to a new target phoneme was 100% correct production. However, as some participants had difficulty, 2/3 correct production in three consecutive sessions was set as the criterion according Sander (1972).

3.1.3.2.4. Home training.

Articulatory practice at sentence level was exclusively a part of home training. A set of simple sentences was provided to the care-taker to minimize the variability in home-training.

3.1.3.3. Post-intervention stage.

Participants underwent a reassessment of articulatory abilities at three data-points P1, P2, and P3 during post intervention stage, similar to pre-intervention stage. On ethical consideration, assessments were carried out at three data points to verify the maintenance of the correct production of the target phonemes. The first post-intervention assessment (P1) was carried out at the termination of intervention stage followed by second assessment (P2) after two weeks and third assessment (P3) post one month of termination of intervention. Figure 3.1 depicts the overview of the intervention process.

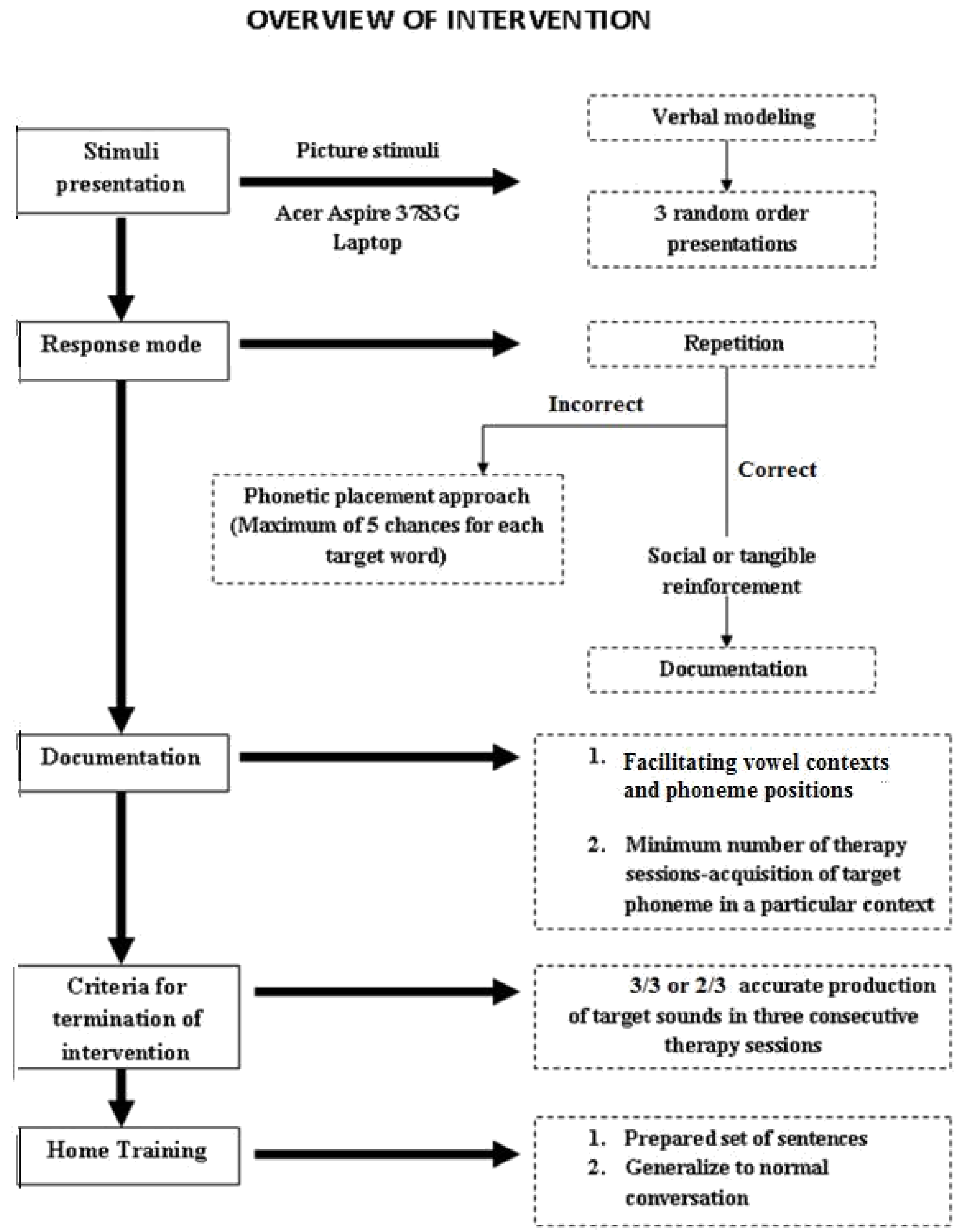


Figure 3.1. An overview of the intervention procedure

The procedure was carried out by the investigator, a native Kannada speaking speech-language pathologist (SLP) with normal speech and language skills. Each participant attended individual assessment and intervention sessions. All the sessions were audio recorded using Olympus-LS-100 and later transcribed using the International Phonetic Alphabet (IPA, 2015).

3.1.3.4. Data analysis

Number of correct responses (NCR) during assessments and intervention; and minimum number of intervention sessions for achieving correct production of the target for 2/3 chances served as the dependent variables. The documented data of dependent variables were subjected to statistical analysis. The data were analyzed both qualitatively (visual analysis) and quantitatively. Qualitative analysis using graphical representations was apt for explaining the findings of the study. Quantitative analysis using inferential statistics did not appear to explain the findings of the study probably because it involved comparing scores of first, mid-, and last-intervention sessions. By mid-intervention session, the median score was 100 for many of the phonetic contexts and the definite change in production from baseline was not apparent from quantitative comparisons. Also, the Wilcoxon Sign Rank test revealed significant difference across pre-post intervention for all the phonetic contexts. This is because, baseline score was zero and post-intervention score was 100% for the target phoneme in most of the phonetic contexts. Hence, quantitative 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. Owing to this, the data was analyzed qualitatively using visual mode i.e. graphical representations.

3.1.3.4.1. Visual Analysis.

Percentage of correct responses in each context was calculated, tabulated, and graphically represented using Microsoft Office Excel (2007). The authors followed Kazdin's (2011) procedure of visual analysis by analyzing the data concerning the magnitude of behavior and latency of change in behavior. The *magnitude of behavior* described the variability in scores across intervention sessions and the *latency of change in behavior* was the duration between B3 and minimum number of session for correct production. Pre-post intervention comparison seldom yielded the required information pertaining to the objectives of the present study. This may be probably because most of the participants had 100% acquisition of the target phonemes in all the contexts considered during post-intervention stage, hence making it difficult to infer the most facilitating context through pre-post intervention comparison. Also, there was consistency in error production across all the three baselines B1, B2, and B3 (0%) of all the target phonemes except for voiced cognates of velar and retroflex which were intervened following their unvoiced cognate earlier. So, the graphical representation includes B3 scores and scores for the minimum number of sessions for correct production.

Minimum number of session required to attain 2/3 or 3/3 correct production of the target phoneme in three consecutive sessions by each participant was tabulated for all the phonetic contexts from visual analysis of graphs. After tabulating, the contexts with least number of sessions was noted down. For example from Table 4.n, it can be seen that for the participant SG, the minimum number of sessions for different contexts are 3, 4, 4, etc. From this, the least session number (LS) i.e. session 3, was noted down. Following this, the NCR score in each vowel context for target in both initial and final positions was documented separately and represented in bar graphs. The vowel context with highest NCR score across three consecutive sessions was considered the most facilitating context for that particular participant. The highly facilitating vowel context in both initial and medial position was noted down separately. Similarly, the above steps were followed for all the participants for each target phoneme considered.

3.1.3.4.2. Reliability measurement

Intra- and inter-judge reliability assessment for performance across sessions was carried out for 50% of the data using Cronbach's Alpha. Intra-judge reliability was carried out by the researcher and inter-judge reliability included two other native Kannada speaking speech-language pathologists. Results are subjected to statistical analysis using SPSS software version 17.

3.2. Phase 2: Validation of Phase 1 results

Validation was not a part of the research proposal and was carried out based on the availability participants, i.e., convenience sampling. The results of phase 1 of the study was validated on two participants, SD and SJA, aged 3.6 years and 4.10 years respectively with phonetic type speech sound disorder. Phase 1 and 2 of the present study had different participants. For Phase-2, inclusion criteria and the assessment procedures was followed as per phase 1. The objective of validation was to examine the applicability of the phoneme facilitating contexts established in Phase 1 of the present study on new participant with SSD. Participant details for validation are provided in Table 3.3.

Table 3.3

The demographic details of phase 2 participants

Sl. No.	Participants	Gender	Age	Articulatory error considered
1.	**SJA**	M	4.10 years	t/k
2.	**SD**	M	3.6 years	t/k, the omission of /k/ in the initial position

The common error observed in both participants was velar /k/ and the validation was confined to this sound. The assessment and intervention were carried out by SLPs who were not part of Phase I and the assessment findings are given in Table 3.4

Table 3.4

Assessment findings of Phase 2 participants

	SJA	**SD**
Type of errors	Word level: Consistent substitution – t/k, d/g, n/l, n/ɭ; more correct productions - /ʈ/ and /ɖ/ in medial position than initial; omissions-medial position sometimes;	Only vowels and dentals present in the initial position; initial consonant deletion; velars not acquired; bilabials acquired in medial position only
Consistency	Both consistent and inconsistent	Inconsistent
Intelligibility rating	3- somewhat intelligible in conversation	5- unintelligible in conversation
Inter-discrimination	Good	Poor
Intra-discrimination	Poor	Poor
Severity (PCC-R)	75% - mildly moderate	25.71% - severe

3.2.1. Intervention procedure.

The procedure of Phase 1 (Figure 3.4) was followed here, but intervention varied regarding

1. Stimuli words: The words with highly facilitating context (as per phase 1) from the continuous assessment wordlist used for intervention (Appendix 8). This variation in stimuli wordlist was to rigor the case study concerning internal validity, external validity and reliability.
2. Duration of intervention: The phonetic contexts showed an effect on the target phonemes within 4 sessions during phase 1 of the study (Graphical representation). Hence, the duration of intervention for each sound was fixed at 4 sessions of 45 minutes each for validation.

3.2.2. Data analysis.

If significant change towards correct production of the target was observed within the stipulated 4 sessions, the findings on facilitating vowel contexts and phoneme positions from the main study is credited as valid.

Chapter 4: Results and Discussion

The present study aimed at investigating the contextual effects of vowels and phoneme positions on the production of speech sounds in native Kannada speaking children with SSD. A total of 15 children with phonetic type SSD were assessed for the articulation abilities at three data points B1 (Baseline 1), B2 (Baseline 2), and B3 (Baseline 3) constituting the pre-intervention stage to ensure error consistency. Following this, they were enrolled for articulation therapy constituting the intervention stage. After the intervention, participants were re-evaluated at three data points P1 (Post-therapy 1), P2 (Post-therapy 2), and P3 (Post-therapy 3) to examine the maintenance of the learnt production, constituting the post-intervention stage. Continuous assessment of the target sound production was also carried out on every 4th session during the intervention stage. Nine frequently misarticulated sounds in Kannada including velars, retroflex, affricates and fricatives (/k/, /g/, /ʈ/, /ɖ/, /ɳ/, /ɭ/, /ʧ/, /ʤ/, and /s/) were considered for speech correction. Among the 15 participants, 6 were enrolled for the correction of /k/, 4 participants for /g/, 5 for /ʈ/, 5 for /ɖ/, 8 for /ɳ/, 3 for /ɭ/, 2 for /ʧ/, 3 for /ʤ/, and 3 for /s/. Intervention involved repetition of words incorporating the target speech sounds in different vowel and phoneme position contexts. On incorrect production, phonetic placement procedures (Van Riper, 1972) were used to teach the correct place of articulation. Number of intervention sessions varied across participants from 4 to 23. Number of correct responses (NCR) and minimum number of sessions to attain 3/3 or 2/3 correct responses in three consecutive sessions served as the measures of the study. The data obtained were analyzed qualitatively through visual analysis of graphical representation and quantitatively using descriptive and inferential statistics.

Qualitative analysis using graphical representations was suitable for explaining the results of the study. Quantitative analysis using inferential statistics did not seem to explain the findings of the study as it involved comparing scores of first, mid-, and last-intervention sessions. By mid-intervention session itself, the median score was 100 for many of the phonetic contexts and the actual change in production from baseline was not evident in quantitative comparisons. Also, the Wilcoxon Sign Rank test revealed significant difference across pre-post intervention for all the phonetic contexts. This is because, baseline score was zero and post-intervention score was 100% regardless of the target phoneme in most of the phonetic contexts. Hence, inferential statistics was not viable to establish the facilitating context for the target phonemes which was the aim of the study. Owing to this, the data was analyzed qualitatively using visual mode i.e. graphical representation has been described extensively for each participant in the following section.

The description of the phonetic contexts with their annotations is provided in Table 4.1 and these annotations will be used frequently to address the phonetic contexts in the result and discussion section. 'T' refers to the target phoneme and in graphs, this 'T' is replaced by respective target phonemes (e.g. k(I)/a/, s(M)/i/, /u:/ʈ(M) and so on).

Table 4.1.

Annotations for phonetic contexts

Phonetic contexts	**Annotations in text**
1. Target phoneme in the initial position followed by vowel /a/	T(I)/a/
2. Target phoneme in the initial position followed by vowel /i/	T(I)/i/
3. Target phoneme in the initial position followed by vowel /u/	T(I)/u/

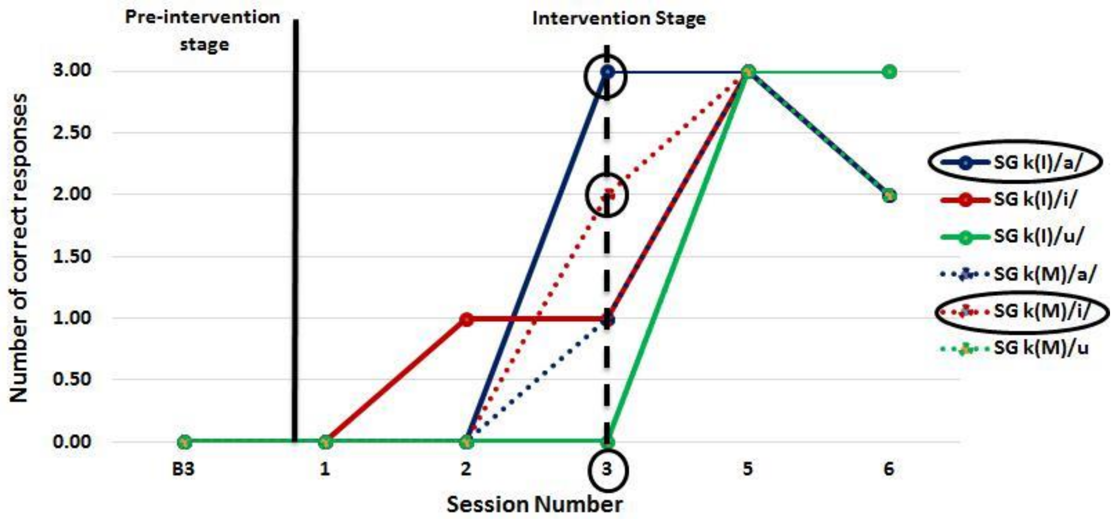
Table 4.1. Continued….

4. Target phoneme in the medial position followed by vowel /a/	T(M)/a/
5. Target phoneme in the medial position followed by vowel /i/	T(M)/i/
6. Target phoneme in the medial position followed by vowel /u/	T(M)/u/

Note: *Statistical comparison of pre-post intervention data did not yield the required information pertaining to the objectives of the present study. This may be probably because most of the participants had 100% acquisition irrespective of the target phonemes in all the contexts considered during post-intervention stage making it difficult to infer the most facilitating context through pre-post intervention comparison. There was consistency in error production across all the three baselines B1, B2, and B3 (0%) of all the target phonemes except for voiced cognates of velar and retroflex which were intervened following their unvoiced cognates earlier. So, the graphical representation for each participant shows the number correct production (Dependent variable 1) at B3 and at the minimum number of sessions for acquiring the target phoneme. Minimum number of sessions (Dependent variable 2) for correct production is* ***encircled*** *in each graph.*

4.1. Facilitating context for unvoiced velar /k/ (6 participants)

1) Participant SG.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.1. Number of correct responses (NCR) vs. sessions for unvoiced velar /k/

Pre-intervention stage: The NCR scores are zero during pre-intervention stage (Fig. 4.1).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was highest (3/3) in the context of T(I)/a/ (e.g. /***ka***ppe/) in three consecutive sessions compared to other contexts (Fig. 4.1).
- *Latency of change in behavior*: By 3rd session a greater change in the behavior was observed in T(I)/a/ and T(M)/i/ contexts (Fig. 4.1).

From Fig. 4.1, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.2.

Table 4.2.

Minimum number of sessions for acquiring the target phoneme /k/ in different phonetic context for SG

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SG	3	4	4	4	3	4

The least session number (LSN) in Table 4.2 is 3. The NCR scores for /k/ in different contexts at session 3 is depicted in Fig. 4.2.

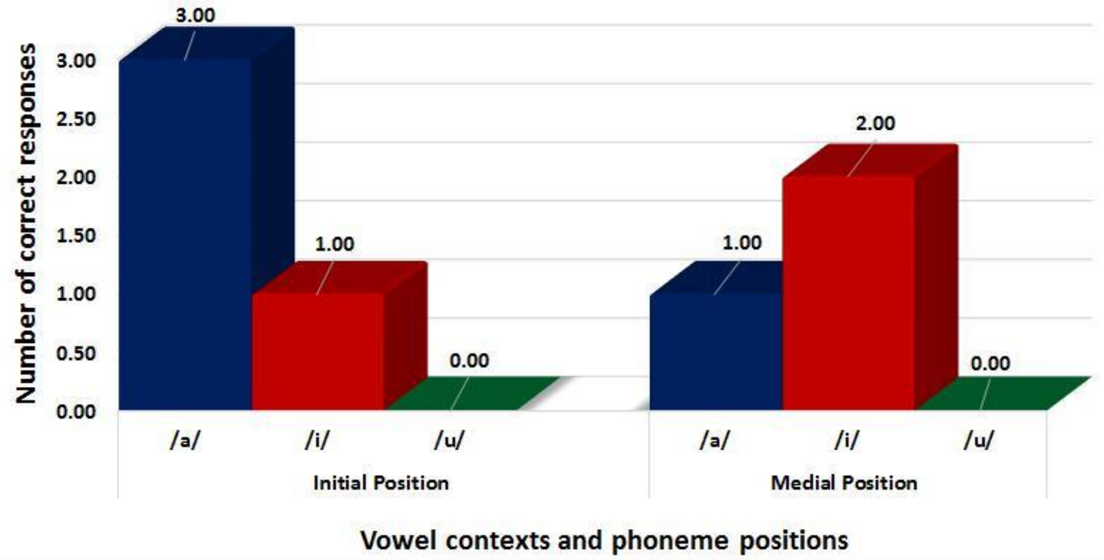
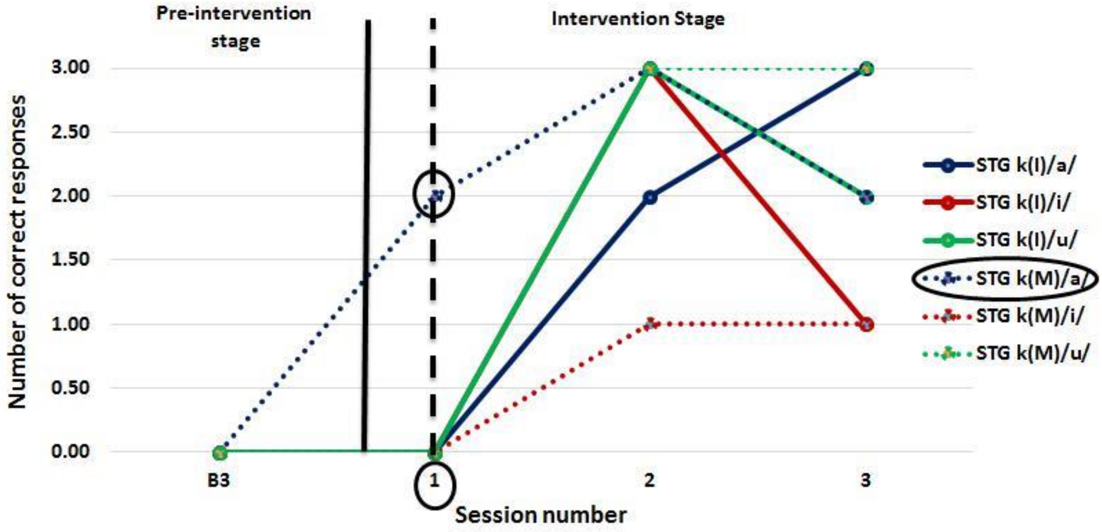


Figure 4.2. Number of correct responses (NCR) in each context at LSN-3 for SG

From Fig. 4.2., it is evident that NCR scores was highest in the context T(I)/a/ (3/3) followed by the context T(M)/i/ (2/3).

Conclusion: Unvoiced velar ***/k/ in the initial position followed by vowel /a/*** as in /***ka***ppe/ (frog), /***ka***bbu/ (sugarcane), etc., was the most facilitating context and secondly ***/k/ in the medial position followed by vowel /i/*** for participant ***SG***.

2) **Participant STG.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.3. Number of correct responses (NCR) vs. sessions for unvoiced velar /k/

Pre-intervention stage: The error production of /k/ was consistent during pre-intervention stage (Fig. 4.3).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was highest (2/3) in the context of T(M)/a/ (e.g. /pu***kka***/) compared to other contexts (Fig. 4.3).
- *Latency of change in behavior*: By 1st session itself a greater change in the behavior was observed T(M)/a/ context (Fig. 4.3).

From Fig. 4.3, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.3.

Table 4.3.

Minimum number of sessions for acquiring the target phoneme /k/ in different phonetic context for STG

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
STG	2	4	2	1	4	2

The least session number (LSN) in Table 4.3 is 1. The NCR scores for /k/ in different contexts at session 1 is depicted in Fig. 4.4.

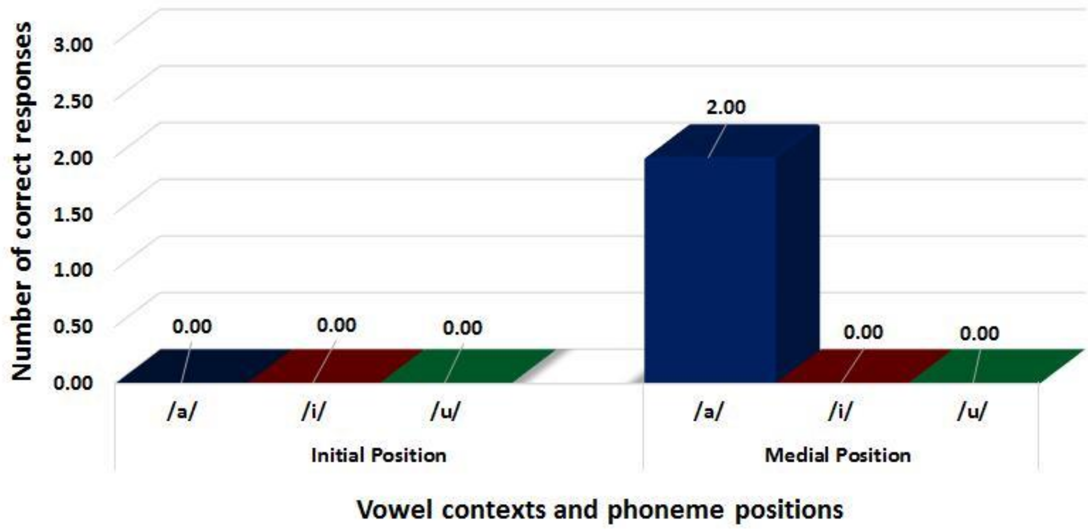
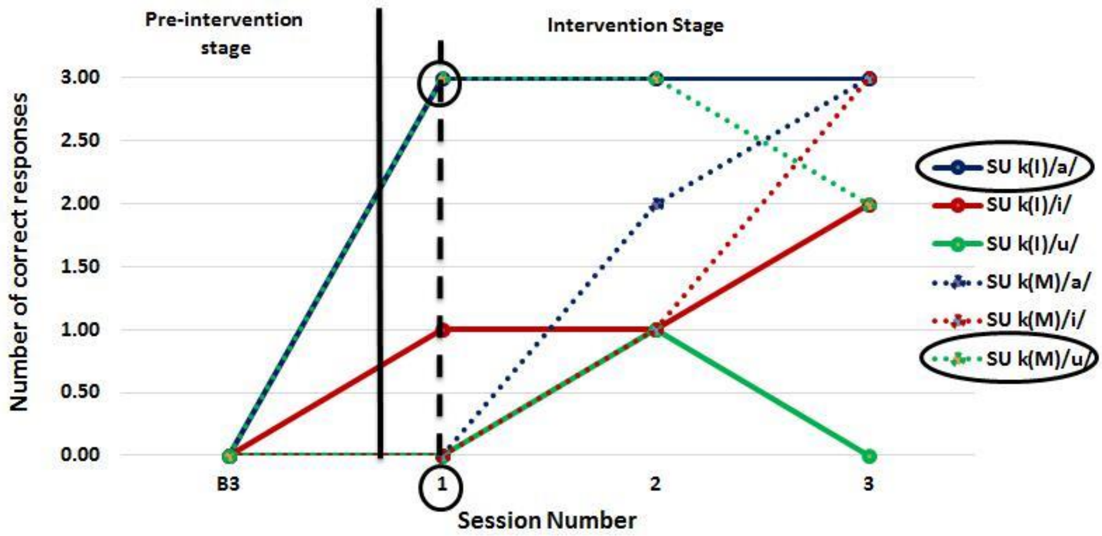


Figure 4.4. Number of correct responses (NCR) in each context at LSN-1 for STG The

NCR score was highest in the context T(M)/a/ (2/3) followed indicating its facilitatory nature (Fig. 4.4).

Conclusion: Velar /k/ ***in the medial position followed by vowel /a/ (T(M)/a/; e.g. /akka/)*** highly ***facilitated*** the production of velar /k/ in ***STG***.

***3)* Participant SU.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.5. Number of correct responses (NCR) vs. sessions for unvoiced velar /k/

Pre-intervention stage: No correct production of /k/ during pre-intervention stage (Fig. 4.5).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was highest (3/3) in the context of T(I)/a/ (e.g. /***ka***ppe/) and T(M)/u/ (e.g. /bu***kku***/) in three consecutive sessions compared to other contexts (Fig. 4.5).

- *Latency of change in behavior*: By 1st session only a noticeable change in the behavior was observed T(I)/a/ and T(M)/u/ context (Fig. 4.5).

From Fig. 4.5, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.4.

Table 4.4.

Minimum number of sessions for acquiring the target phoneme /k/ in different phonetic context for SU

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SU	1	3	>3	2	3	1

The least session number (LSN) in Table 4.4 is 1. The NCR scores for /k/ in different contexts at session 1 is depicted in Fig. 4.6.

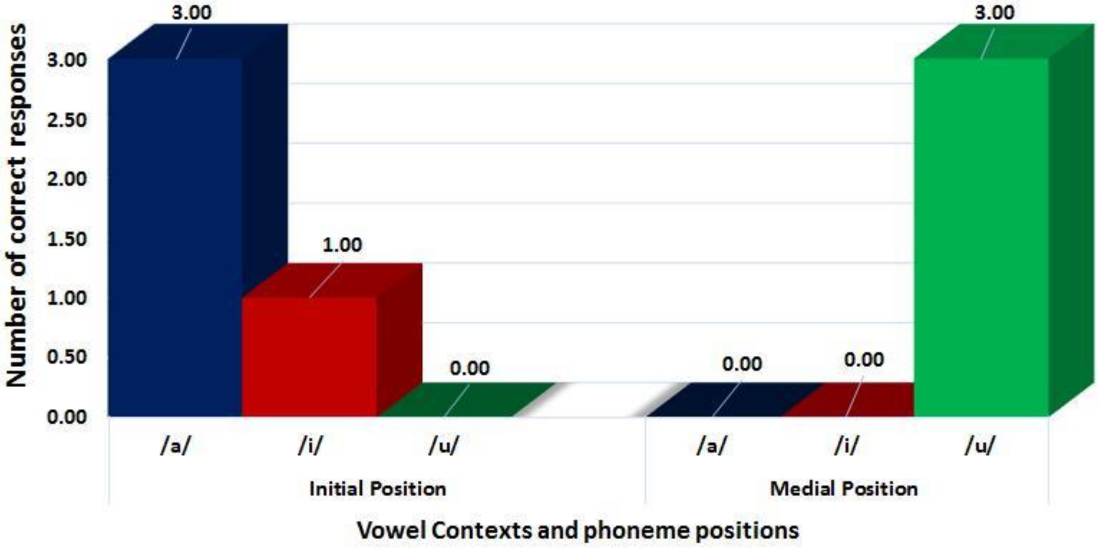
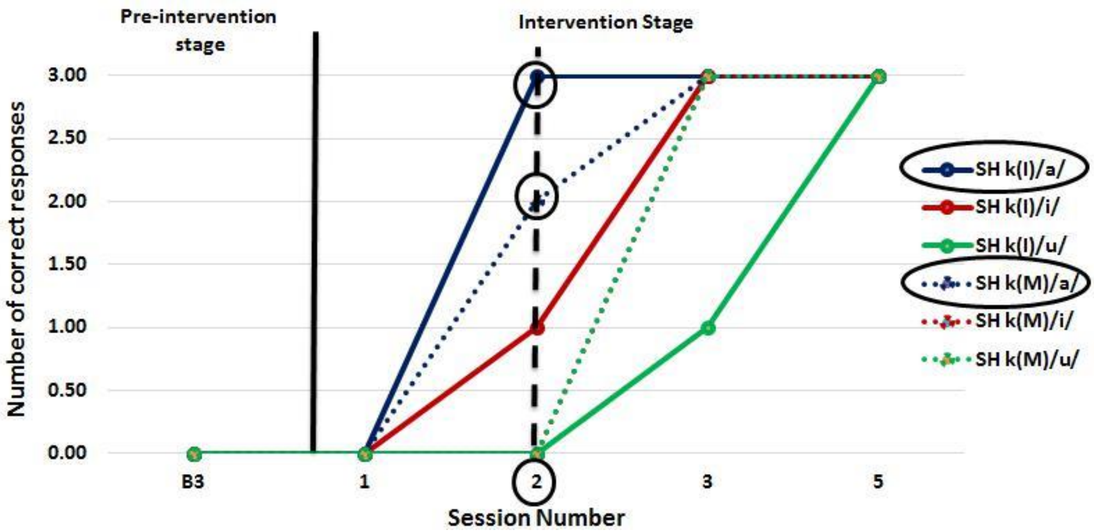


Figure 4.6. Number of correct responses (NCR) in each context at LSN-1 for SU

It is apparent from Fig. 4.6, that NCR scores was highest in the vowel context /a/ (3/3) with /k/ in the initial position and vowel /u/ (3/3) with /k/ in the medial position of the word.

Conclusion: Velar /k/ in the initial position followed by ***vowel /a/, (T(I)/a/; /e.g. /kappe/)*** highly ***facilitated*** the production of ***/k/*** in ***SU*** similar to **SJe;** secondly ***/k/ in the medial position followed by vowel /u/ (e.g. /bukku/)*** also facilitated.

4) **Participant SH.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.7. Number of correct responses (NCR) vs. sessions for unvoiced velar /k/

Pre-intervention stage: The NCR scores were zero for /k/ production during pre-intervention stage (Fig. 4.7).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was highest (3/3) in the context of T(I)/a/ (e.g. /***ka***ppe/) followed by T(M)/a/ (e.g. /a***kka***/) in three consecutive sessions compared to other contexts (Fig. 4.7).

- *Latency of change in behavior*: By 2nd session a greater change in the behavior was observed T(I)/a/ and T(M)/a/ contexts (Fig. 4.7).

From Fig. 4.7, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.5.

Table 4.5.

Minimum number of sessions for acquiring the target phoneme /k/ in different phonetic context for SH

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SH	2	3	4	2	3	3

The least session number (LSN) in Table 4.5 is 2. The NCR scores for /k/ in different contexts at session 2 is depicted in Fig. 4.8.

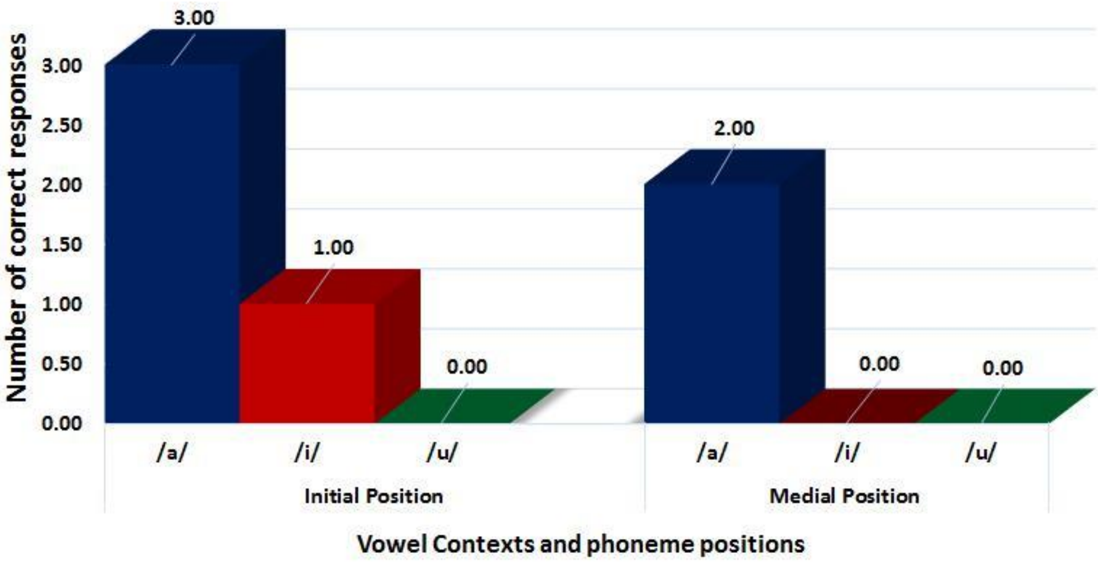
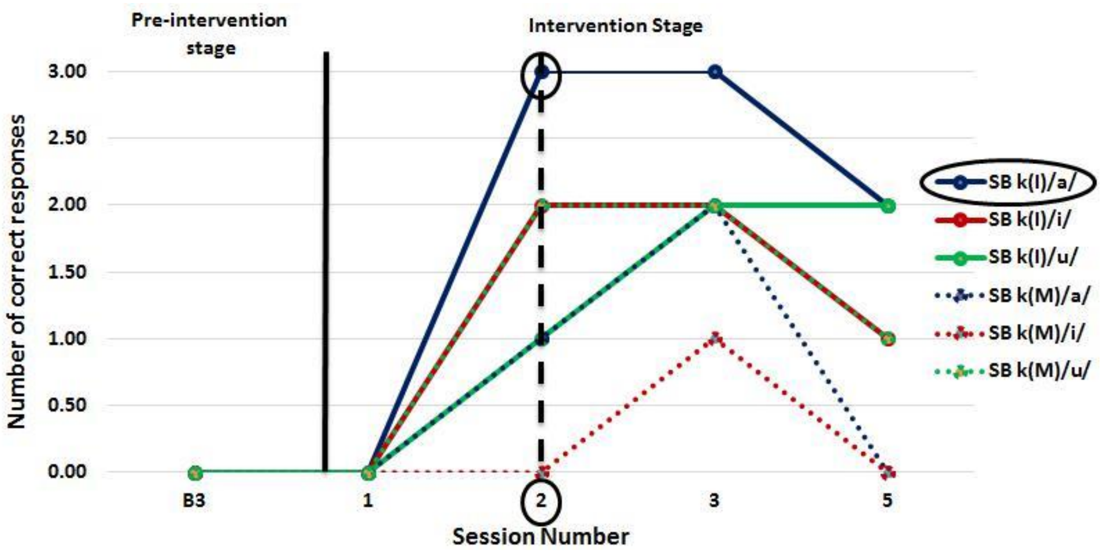


Figure 4.8. Number of correct responses (NCR) in each context at LSN-2 for SH

It is evident from Fig. 4.8 that NCR scores was highest in the vowel context /a/ with /k/ in either initial (3/3) or medial (2/3) position of the word.

Conclusion: The most facilitating contexts were ***vowel /a/ with target phoneme in either initial position (T(I)/a/; e.g. /kappe/)*** similar to SJe and SU ***or in medial position (e.g. /akka/).***

5) Participant SB.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ; most facilitating context/s - }

Figure 4.9. Number of correct responses (NCR) vs. sessions for unvoiced velar /k/

Pre-intervention stage: There was consistency in error production of /k/ during pre-intervention stage (Fig. 4.9).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was highest (3/3 or 2/3) in the context of T(I)/a/ (e.g. /***ka***ppe/) (Fig. 4.9).

- *Latency of change in behavior*: By 2nd session a greater change in the behavior was observed T(I)/a/ context (Fig. 4.9).

From Fig. 4.9, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.6.

Table 4.6.

Minimum number of sessions for acquiring the target phoneme /k/ in different phonetic context for SB

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SB	2	5	3	5	5	5

The least session number (LSN) in Table 4.6 is 2. The NCR scores for /k/ in different contexts at session 2 is depicted in Fig. 4.10.

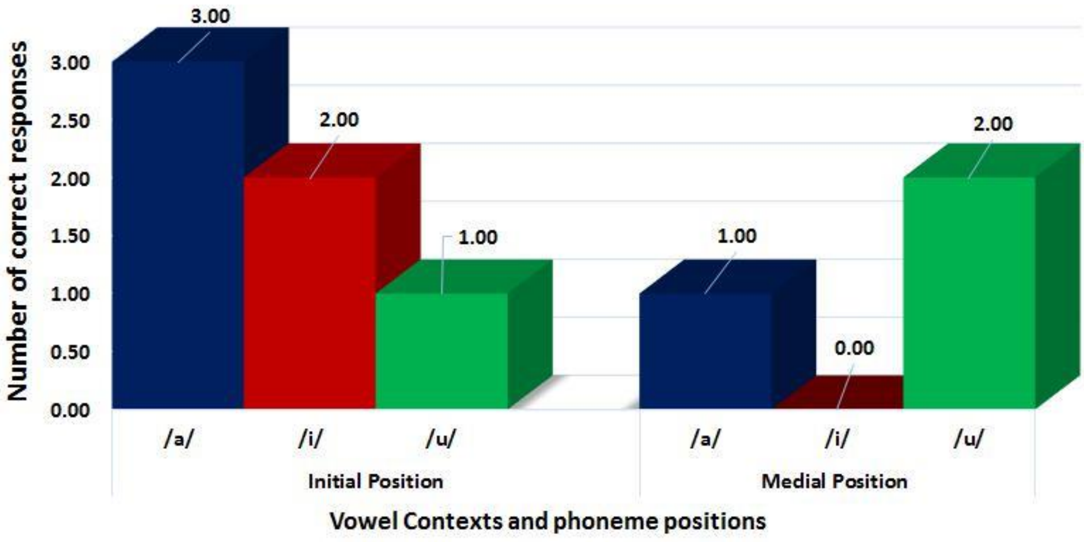
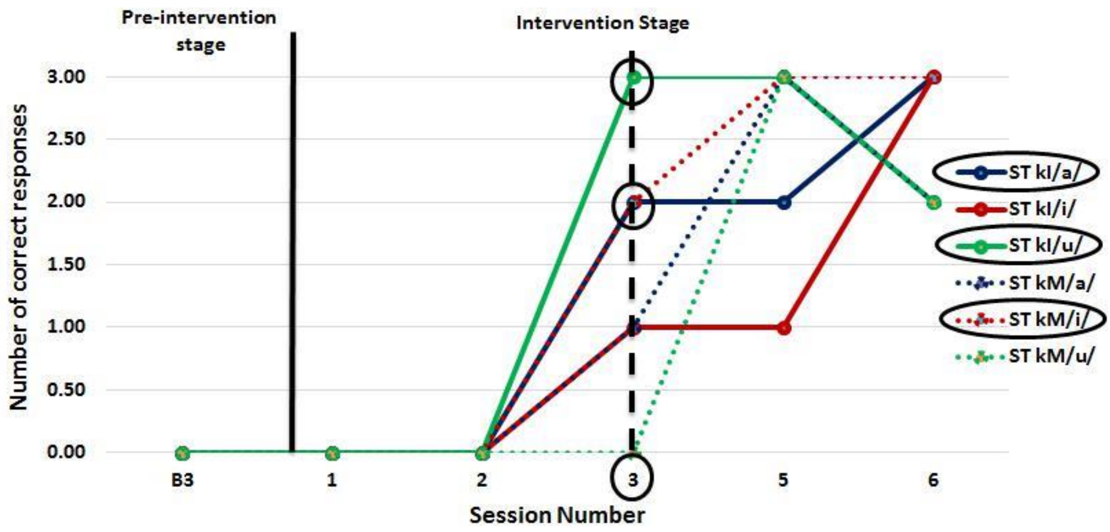


Figure 4.10. Number of correct responses (NCR) in each context at LSN-2 for SB

It is apparent from Fig. 4.10, that NCR score is highest in the vowel context /a/ with /k/ in initial (3/3) position of the word.

Conclusion: The ***context vowel /a/ with target in the initial position (T(I)/a/; e.g. /kappe/)*** highly ***facilitated*** the production of ***velar /k/*** in ***SB*** similar to participants SJe, SU, and SH.

6) **Participant ST.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.11. Number of correct responses (NCR) vs. sessions for unvoiced velar /k/

Pre-intervention stage: No correct production of /k/ during pre-intervention stage (Fig. 4.11).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was highest (3/3 or 2/3) in the context of T(I)/u/ (e.g. /***ku***ḍi/), T(M)/i/ (e.g. /a***kki***/) and T(I)/a/ (e.g. /***ka***ppe/) (Fig. 4.11).

- *Latency of change in behavior*: By 3rd session a greater change in the behavior was observed T(I)/u/, T(I)/a/, and T(M)/i/ contexts (Fig. 4.11).

From Fig. 4.11, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.7.

Table 4.7.

Minimum number of sessions for acquiring the target phoneme /k/ in different phonetic context for ST

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
ST	3	5	3	4	3	4

The least session number (LSN) in Table 4.7 is 3. The NCR scores for /k/ in different contexts at session 3 is depicted in Fig. 4.12.

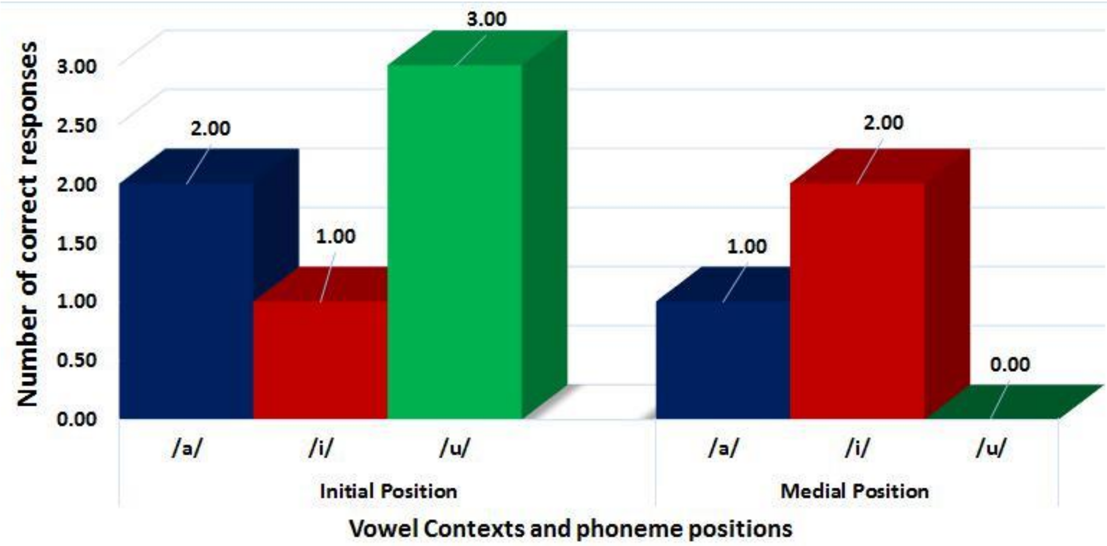


Figure 4.12. Number of correct responses (NCR) in each context at LSN-3 for ST

The NCR scores was highest in the vowel context /u/ with /k/ in initial (3/3) position, in vowel context /a/ (2/3) with /k/ in the initial position, and in the context of vowel /i/ with /k/ in the medial position (2/3) of the word for ST (Fig. 4.12).

Conclusion: The ***context vowel /i/ with target in the medial position*** and ***target in the initial position followed by either vowel /u/ or /a/ facilitated*** the production of ***velar /k/*** in ***ST***.

In sum, T(I)/a/ (e.g. /***ka***ppe/) was the highly facilitating phonetic context for /k/ for 5 out of 6 participants. Also, the minimum number of sessions required for the correct production of /k/ was relatively less for T(I)/a/ context compared to other contexts. This is attributable to the physiological basis of vowel /a/ production during which the tongue is free to move in any direction without interfering with the upward movement of tongue dorsum for producing velar /k/ (Bauman-Waengler, 2012). This view is supported by Swisher's physiological reasoning (1973) stating that the context minimally interfering with the error sound is facilitating. In addition, vowel /a/ has less coarticulatory constraints (Sylak-Glassman, 2014). Also, the upward movement of dorsum of the tongue is appreciably visible due to relatively wide open mouth during production of /a/ compared to the other two vowels /i/ and /u/ leading to easier production of /k/ during intervention. Vowel /a/ also facilitated the production of velars in Malayalam speaking children with hearing impairment (Anu Rose, 2017). On the other hand, results are not in agreement with Bleile's (1996) clinical observation reporting that velars are facilitated when positioned before vowel /u/ in English and are in partial consonance with Bauman-Waengler (2012) findings stating along with high back vowels even low vowels facilitate.

With respect to the phoneme position, Shishira and Sreedevi (2013) and Sushma and Sreedevi (2013) reported initial position favoring the acquisition of velars during normal speech development. Initial position of the target phoneme is facilitating its production in SG, SH, SB and SU attributing to the fact that target in the initial position receives the first neural commands with least influence by preceding positions of articulators (Branigan, 1976). In addition, initial syllables in Kannada are relatively more stressed and are attended to and extracted perceptually by toddlers (Echols & Newport, 1992). This result is not in consonance with Bleile's (1996) findings reporting that final position favours velar production. These differnces across langauges can be related to the differnces in stress patterns between Kannada and English.

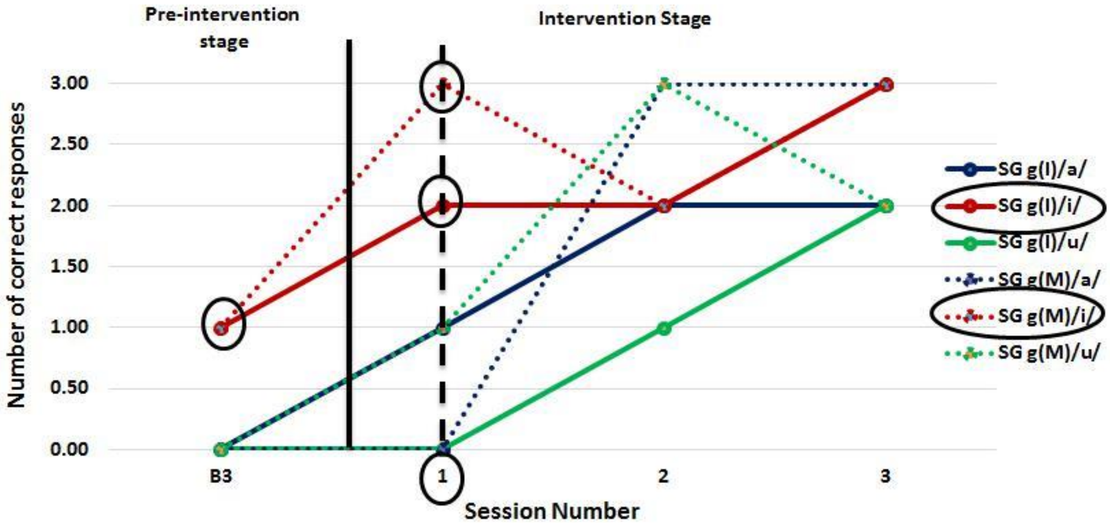
The contexts T(M)/i/ (e.g. /a***kki***/) and T(M)/a/ (e.g. /a***kka***/) highly facilitated the production of velar /k/ in ST and STG respectively. Medial position facilitated the production of velar /k/ in both ST and SB which is perhaps due to the minimal influence by the articulatory requirements of adjacent sounds in medial position (Kent, 1982). Also, the stimuli included geminate forms of the target occurring in medial position with more stress compared to singletons in the initial position facilitating the correct production. 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, Schuckers, & Daniloff, 1980) making them facilitating for speech sound production.

An interesting finding was that vowel /i/ facilitated /k/ in ST and not vowel /a/. This observation is attributable to the physiological fact that during the production of vowel /i/ the tongue blade is raised and the dorsum is free for coarticulation; there is less distance between the tongue and the palate facilitating easy upward movement of tongue dorsum along with tongue blade in ST. This difference in facilitating vowel context and phoneme position of ST compared to other participants may be probably due to higher severity of articulartory problems in ST.

Thus, the results indicate target in the initial position followed by vowel /a/, ***T(I)/a/*** to be the highly facilitating context for the perceptually correct production of ***velar /k/*** in majority of the children with ***mild-mild to moderate speech sound disorders*** and target in the medial position followed by vowel /i/, ***T(M)/i/*** in children with ***moderately severe speech sound disorders***.

4.2. Facilitating context for voiced velar /g/ (4 participants)

1) Participant SG.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.13. Number of correct responses (NCR) vs. sessions for voiced velar /g/

Pre-intervention stage: Velar /g/ started emerging in both initial and medial positions in the context of vowel /i/ during pre-intervention stage (Fig. 4.13).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was highest (3/3 or 2/3) in the context of T(I)/i/ (e.g. /***gi***laki/) and T(M)/i/ (e.g. /ma***ggi***/) (Fig. 4.13).
- *Latency of change in behavior*: By 1st session a greater change in the behavior was observed T(I)/i/ and T(M)/i/ contexts (Fig. 4.13).

From Fig. 4.13, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.8.

Table 4.8.

Minimum number of sessions for acquiring the target phoneme /g/ in different phonetic context for SG

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SG	5	1	3	2	1	2

The least session number (LSN) in Table 4.8 is 1. The NCR scores for /g/ in different contexts at session 1 is depicted in Fig. 4.14.

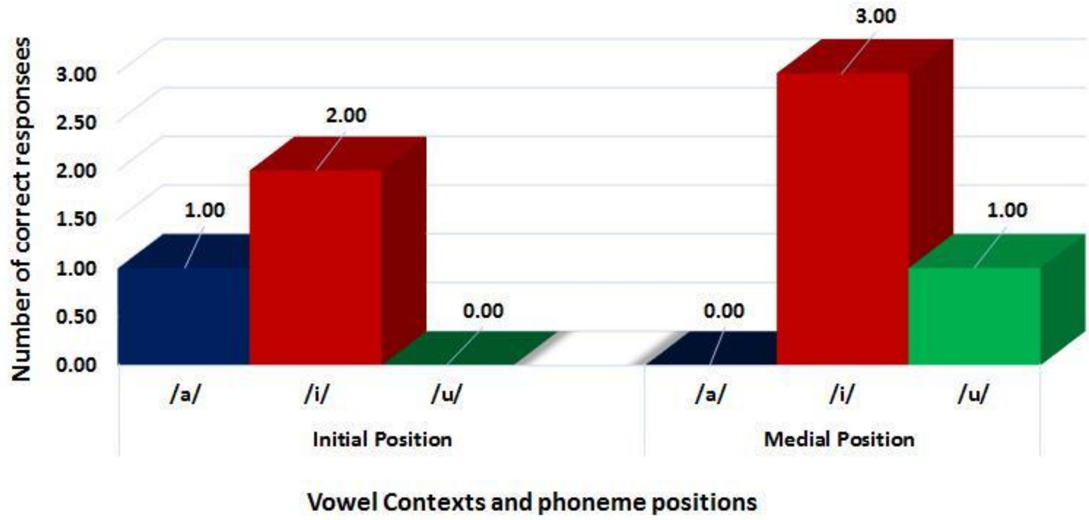
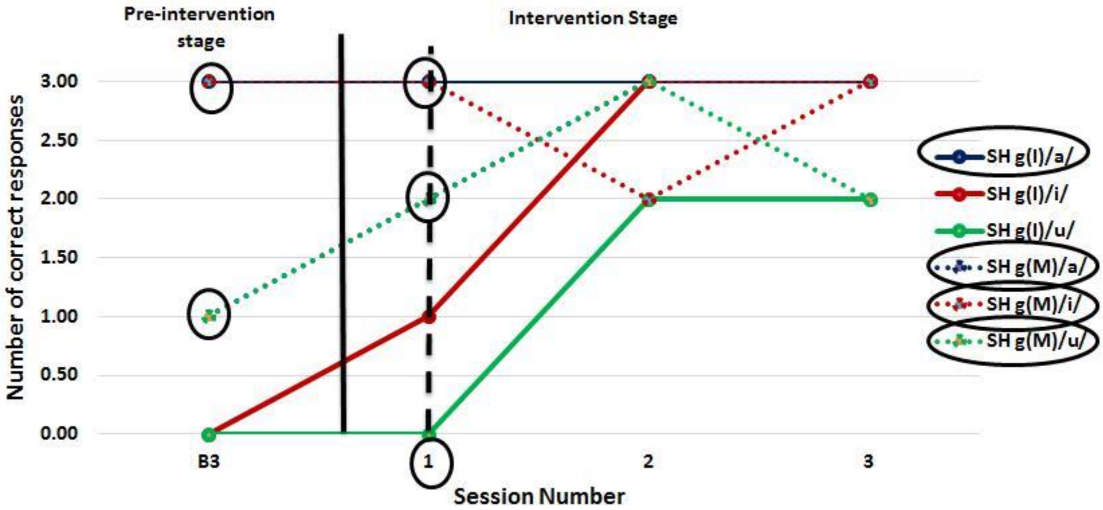


Figure 4.14. Number of correct responses (NCR) in each context at LSN-1 for SG The

NCR score was highest when /g/ was either in the initial or medial position in the context of vowel /i/ (Fig. 4.14).

Conclusion: Voiced velar ***/g/*** was most ***facilitated*** either in the *initial or medial position* in the context of ***vowel /i/*** in ***SG***.

2) **Participant SH.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.15. Number of correct responses (NCR) vs. sessions for voiced velar /g/

Pre-intervention stage: Velar /g/ emerged in both initial and medial positions in the context of vowel /a/ and /i/ respectively during pre-intervention stage (Fig. 4.15).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was highest (3/3) in the context of T(I)/a/ (e.g. /***ga***dde/) followed by T(M)/i/ (e.g. /ma***ggi***/), T(M)/a/ (e.g. /agasa/), and T(M)/u/ (e.g. /magu/) (Fig. 4.15).

- *Latency of change in behavior*: By 1st session a greater change in the behavior was observed T(I)/a/ followed by T(M)/i/, T(M)/a/, and T(M)/u/ contexts (Fig. 4.15).

From Fig. 4.15, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.9.

Table 4.9.

Minimum number of sessions for acquiring the target phoneme /g/ in different phonetic context for SH

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SH	1	2	2	1	1	1

The least session number (LSN) in Table 4.9 is 1. The NCR scores for /g/ in different contexts at session 1 is depicted in Fig. 4.16.

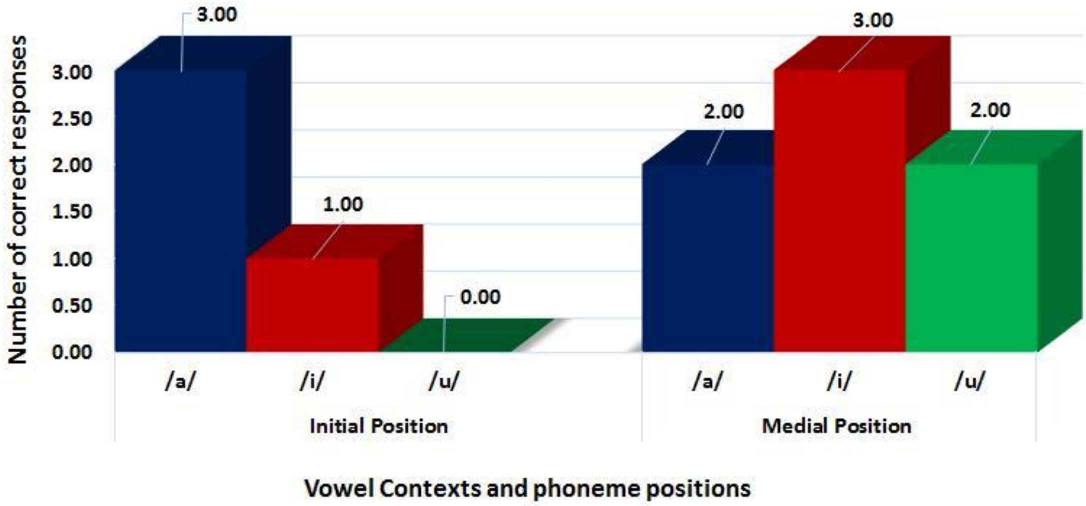
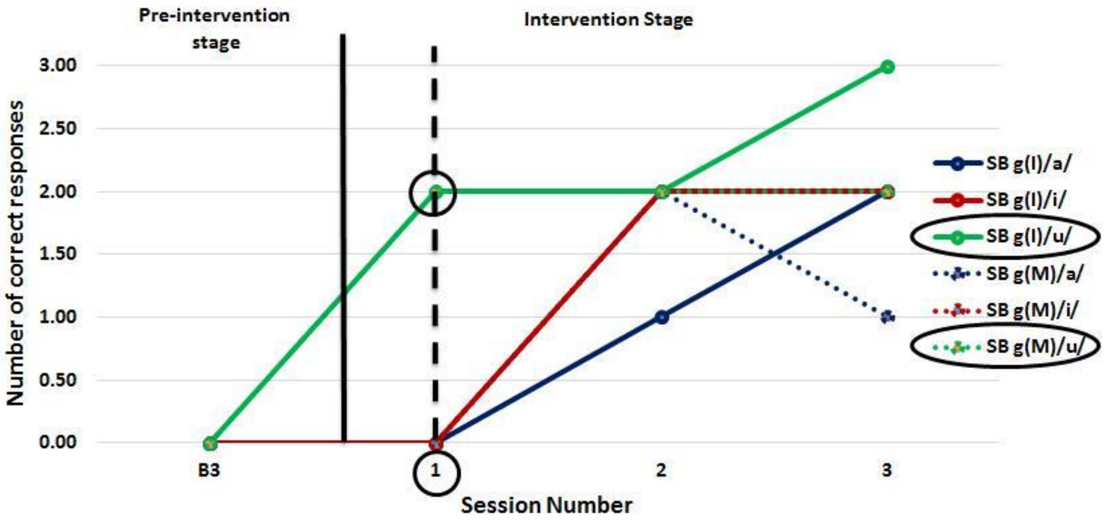


Figure 4.16. Number of correct responses (NCR) in each context at LSN-1 for SH

The NCR scores was highest in T(I)/a/ followed by T(M)/i/, T(M)/a/, and T(M)/u/ contexts (Fig. 4.16).

Conclusion: Voiced velar ***/g/*** in the ***initial position followed by vowel /a/*** was the highly ***facilitating*** context in ***SH*** similar to the observation during the production of voiceless velar /k/ followed by T(M)/i/, T(M)/a/, and T(M)/u/ contexts.

3) Participant SB.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.17. Number of correct responses (NCR) vs. sessions for voiced velar /g/ *Pre-intervention stage:* No production of /g/ was present during pre-intervention stage (Fig. 4.17).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was highest (3/3) in the context of T(I)/u/ (e.g. /***gu***ddali/) followed by T(M)/u/ (e.g. /magu/) (Fig. 4.17).

- *Latency of change in behavior*: By 1st session a greater change in the behavior was observed T(I)/u/ and T(M)/u/ contexts (Fig. 4.17).

From Fig. 4.17, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.10.

Table 4.10.

Minimum number of sessions for acquiring the target phoneme /g/ in different phonetic context for SB

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SB	3	2	1	4	2	1

The least session number (LSN) in Table 4.10 is 1. The NCR scores for /g/ in different contexts at session 1 is depicted in Fig. 4.18.

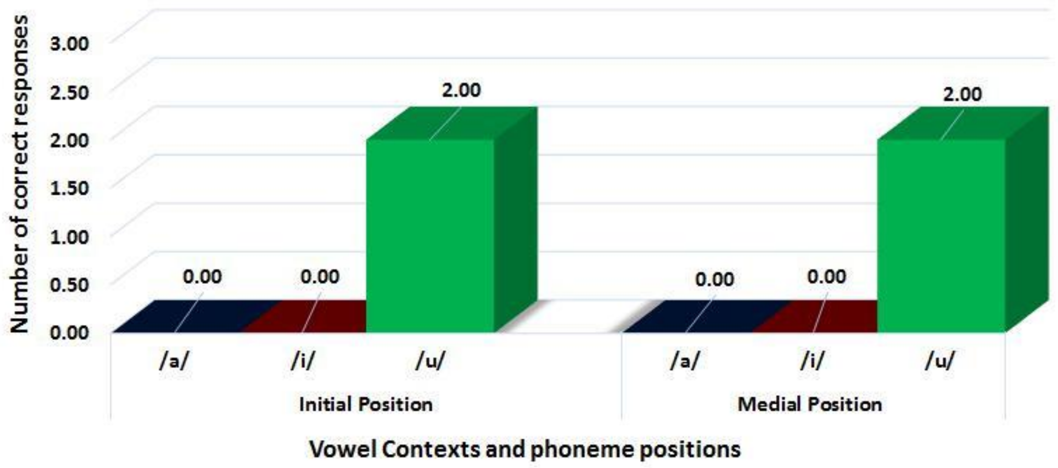
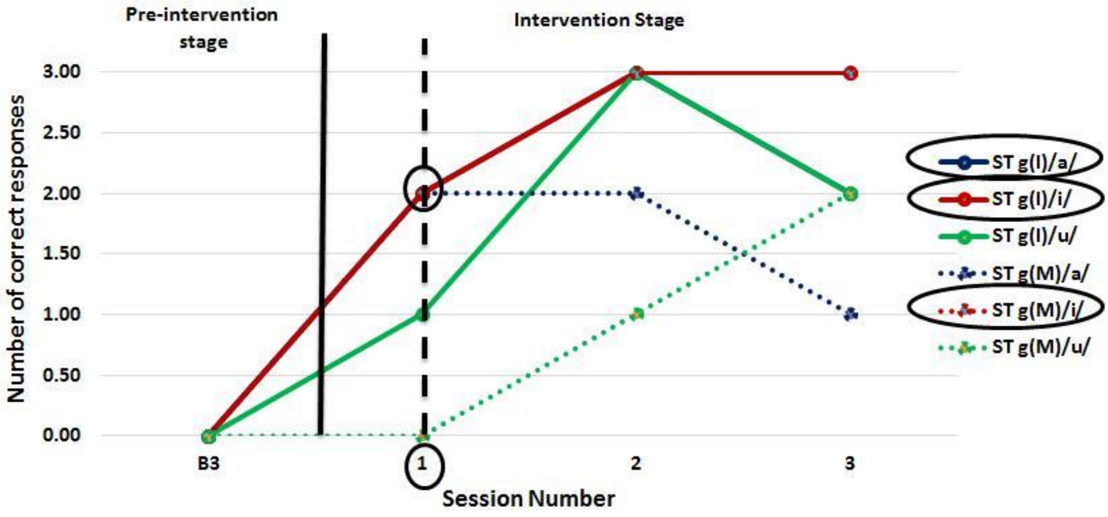


Figure 4.18. Number of correct responses (NCR) in each context at LSN-1 for SB

The NCR scores was highest when velar /g/ was either in the initial or medial position followed by vowel /u/, T(I)/u/ and T(M)/u/ contexts (Fig. 4.18).

Conclusion: Voiced velar ***/g/*** in either ***initial or medial position followed by vowel /u/*** was the most ***facilitating context*** for ***SB***.

4) **Participant ST.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ○; most facilitating context/s - ⬭ }

Figure 4.19. Number of correct responses (NCR) vs. sessions for voiced velar /g/

Pre-intervention stage: No production of /g/ during pre-intervention stage (Fig. 4.19).

Intervention stage:

- *Magnitude of behavior*: The contexts T(I)/i/ (e.g. /***gi***laki/) followed by T(M)/i/ (e.g. /ma***ggi***/) and T(I)/a/ (e.g. /***ga***dde/) had the highest scores for the production of phoneme /g/ (Fig. 4.19).

- *Latency of change in behavior*: By 1st session a greater change in the behavior was observed T(I)/i/, T(M)/i/, and T(I)/a/ contexts (Fig. 4.19).

From Fig. 4.19, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.11.

Table 4.11.

Minimum number of sessions for acquiring the target phoneme /g/ in different phonetic context for ST

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
ST	1	1	2	1	1	3

The least session number (LSN) in Table 4.11 is 1. The NCR scores for /g/ in different contexts at session 1 is depicted in Fig. 4.20.

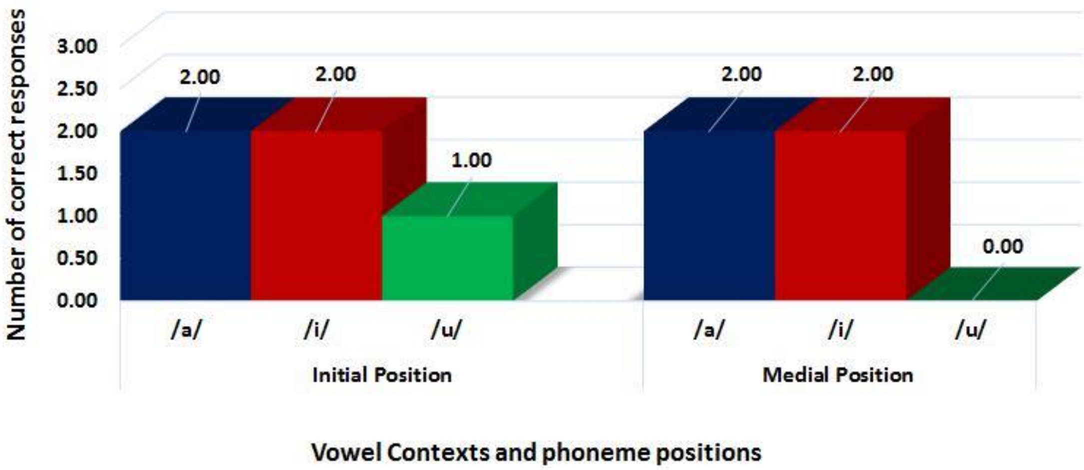


Figure 4.20. Number of correct responses (NCR) in each context at LSN-1 for ST

The NCR scores was highest when velar /g/ was either in the initial or medial position followed by vowel /a/ and /i/ (Fig. 4.20).

Conclusion: Voiced velar ***/g/*** in either ***initial or medial position followed by vowel /i/*** was the highly ***facilitating contexts*** for ***ST*** followed by /g/ in the initial position followed by vowel /a/.

The graphical analysis of voiced velar /g/ revealed different contexts facilitating /g/ in each participant. Vowel /a/ with target in initial position, T(I)/a/ facilitated the production of /g/ in SH and vowel /i/ with target in either initial or medial position, T(I)/i/ and T(M)/i/ facilitated the production of /g/ in SG and ST. These findings are similar to what was observed for the production of /k/ except for SG which is probably due to the physiological compatibility in terms of distance between the tongue and the palate during the production of vowel /i/.

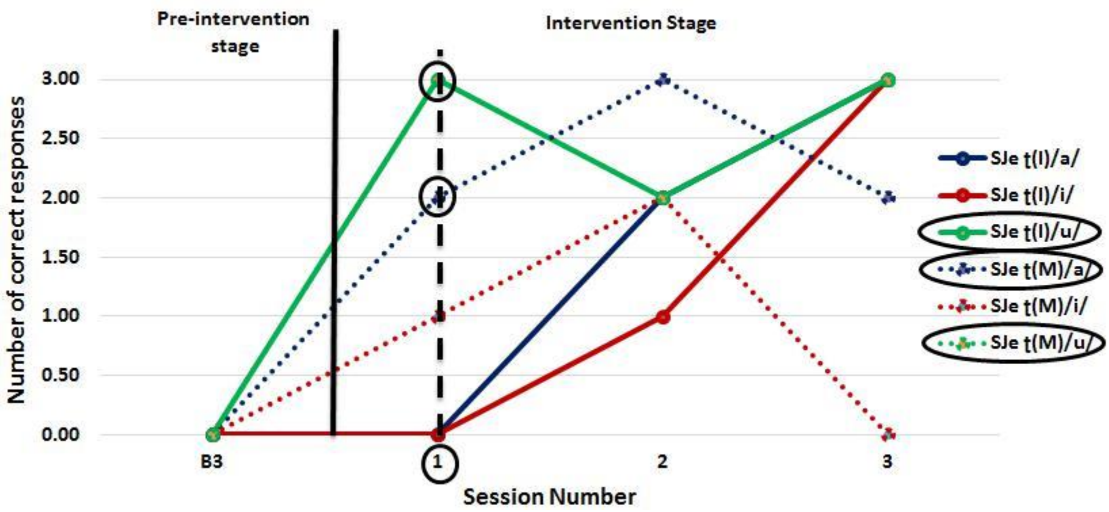
For participant ST, both velars, /k/ and /g/ in medial position followed by vowel /i/ was highly facilitating which was not observed in other participants. This may be probably due to higher severity level of ST compared to other participants indicating severity level of the articulatory errors and time required for generalization are directly proportional.

For participant SB, irrespective of velar /g/ position, vowel /u/ is facilitating. This can be due to similar place of articulation for /u/ and /g/ facilitating each other's production (Swisher, 1973). Bleile (1996) and Bauman-Waengler (2012) also report vowel /u/ facilitating the production of velars.

Overall, the results did not confine to one facilitating context and varied across participants for /g/. There was more than one context facilitating the production of /g/ which can be accredited to the fact that participants had prior knowledge on velar place of articulation as voiceless velar /k/ was intervened before voiced /g/ and the application of articulatory phonetics (physiological) with voicing aspect would have differed across the participants.

4.3. Facilitating context for voiceless retroflex /ʈ/ (5 participants)

1) Participant SJe.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.21.*Number of correct responses (NCR) vs. sessions for unvoiced retroflex /ʈ/

Pre-intervention stage: No production of /ʈ/ during pre-intervention stage (Fig. 4.21).

Intervention stage:

- *Magnitude of behavior*: The contexts T(I)/u/ (e.g. /***ʈu:***ru/), T(M)/u/ (e.g. /gu***ʈʈu***/), followed by T(M)/a/ (e.g. /a***ʈʈ***a/) had highest correct production of the target sound (Fig. 4.21).

- *Latency of change in behavior*: By 1st session a substantial change in the behavior was observed T(I)/u/, T(M)/u/, and T(M)/a/ contexts (Fig. 4.21).

From Fig. 4.21, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.12.

Table 4.12.

Minimum number of sessions for acquiring the target phoneme /ʈ/ in different phonetic context for SJe

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SJe	2	3	1	1	4	1

The least session number (LSN) in Table 4.12 is 1. The NCR scores for /ʈ/ in different contexts at session 1 is depicted in Fig. 4.22.

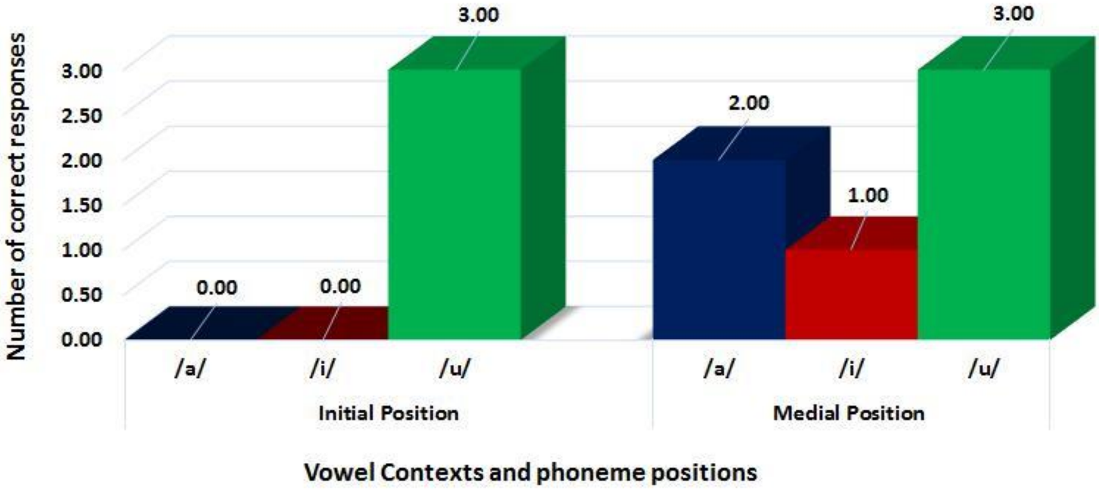
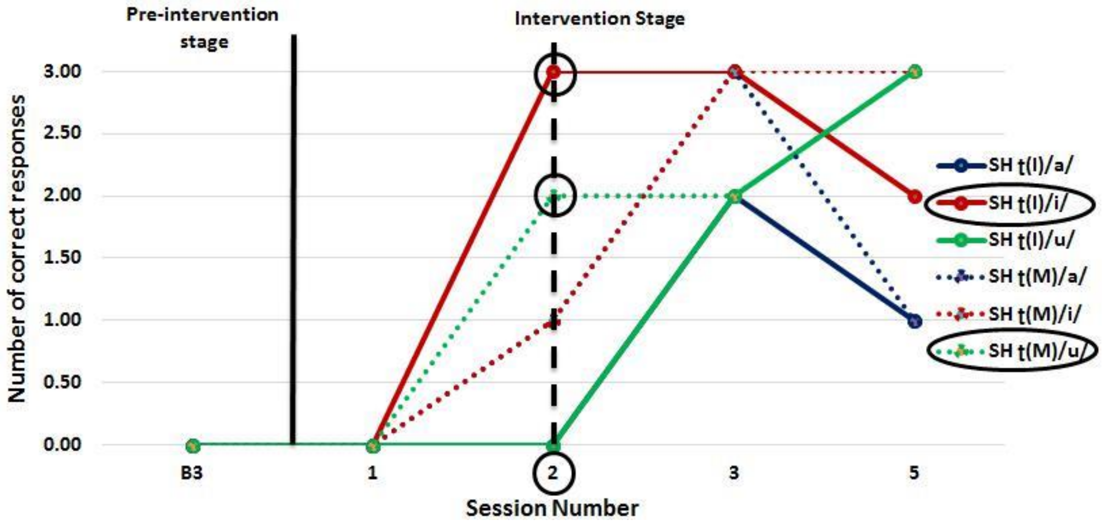


Figure 4.22. Number of correct responses (NCR) in each context at LSN-1 for SJe

It is evident from Fig. 4.22., that the NCR score is highest when velar /g/ was either in the initial or medial position followed by vowel /u/; secondly, when velar in the medial position followed by vowel /a/.

Conclusion: The ***vowel /u/*** constantly facilitated the production of ***unvoiced retroflex /ʈ/in both the phoneme initial and medial positions*** for ***SJe.***

2) Participant SH.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.23. Number of correct responses (NCR) vs. sessions for unvoiced retroflex /ʈ/

Pre-intervention stage: There was consistent error production of /ʈ/ during pre-intervention stage (Fig. 4.23).

Intervention stage:

- *Magnitude of behavior*: The contexts T(I)/i/ (e.g. /***ʈi***:vi/) and T(M)/u/ (e.g. /gu***ʈʈu***/) have highest correct production of the target sound (Fig. 4.23).

- *Latency of change in behavior*: By 2nd session a greater change in the behavior was observed T(I)/i/ and T(M)/u/ (Fig. 4.23).

From Fig. 4.23, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.13.

Table 4.13.

Minimum number of sessions for acquiring the target phoneme /ʈ/ in different phonetic context for SH

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SH	6	2	3	5	3	2

The least session number (LSN) in Table 4.13 is 2. The NCR scores for /ʈ/ in different contexts at session 2 is depicted in Fig. 4.24.

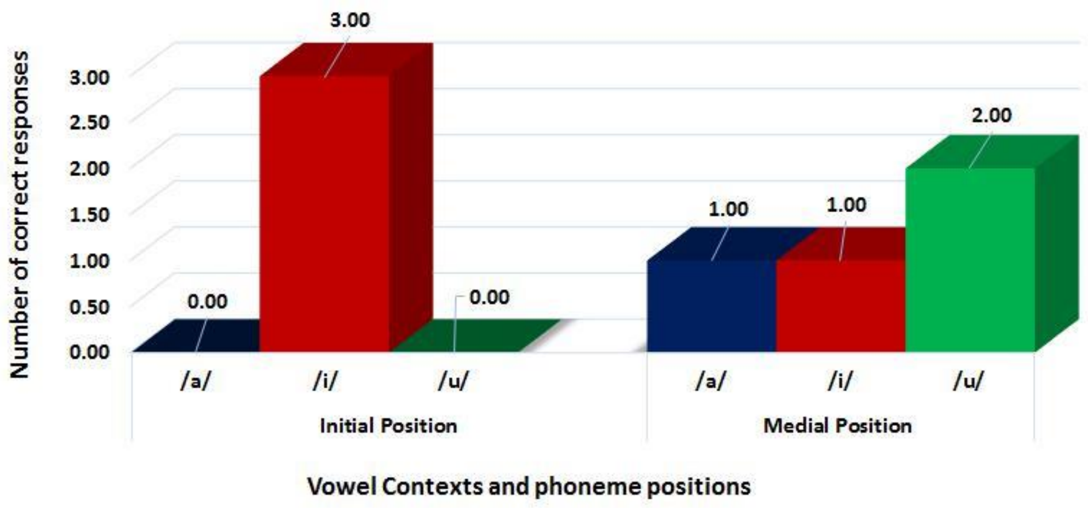
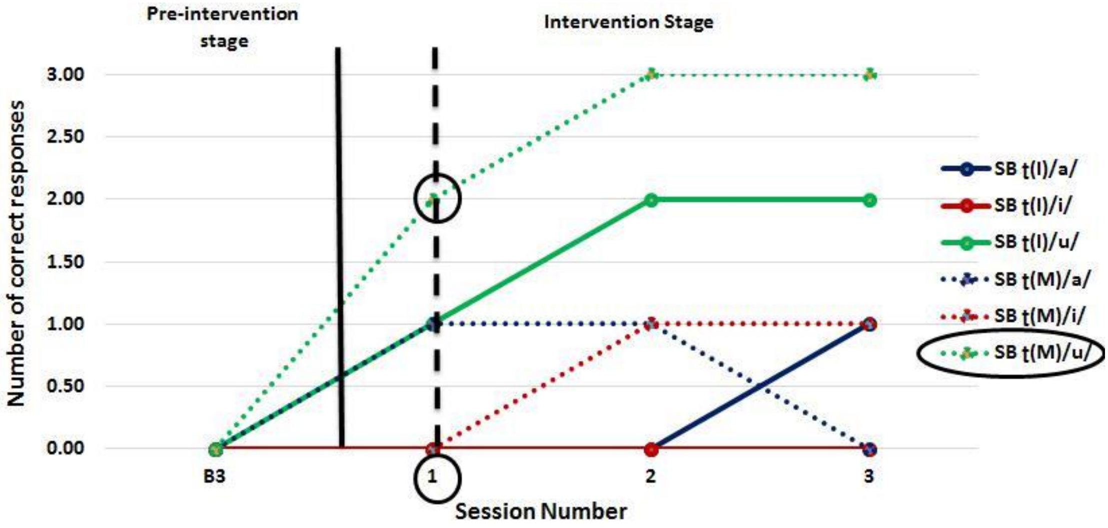


Figure 4.24. Number of correct responses (NCR) in each context at LSN-2 for SH

It is evident from Fig. 4.24., that the NCR score is highest when retroflex /ʈ/ is in the initial position followed by vowel /i/ and when it is in the medial position followed by vowel /u/.

Conclusion: ***Unvoiced retroflex /ʈ/*** was ***facilitated*** in the context when it was in the ***initial position followed by vowel /i/*** and in the ***medial position followed by vowel /u/*** for ***SH***.

3) **Participant SB.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.25.*Number of correct responses (NCR) vs. sessions for unvoiced retroflex /ʈ/

Pre-intervention stage: The NCR scores were zero for the production of /ʈ/ during pre-intervention stage (Fig. 4.25).

Intervention stage:

- *Magnitude of behavior*: It is apparent from Fig. 4.25, that contexts T(M)/u/ (e.g. /gu***ʈʈu***/) have highest NCR scores followed by T(I)/u/ (e.g. /***ʈu:***ru/)(Fig. 4.25).

- *Latency of change in behavior*: By 1st session a good change in the behavior was observed for T(I)/u/ and T(M)/u/ (Fig. 4.25).

From Fig. 4.25, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.14.

Table 4.14.

Minimum number of sessions for acquiring the target phoneme /ʈ/ in different phonetic context for SB

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SB	IC	IC	2	IC	IC	1

IC- inconclusive due to high variability in performance

The least session number (LSN) in Table 4.14 is 1. The NCR scores for /ʈ/ in different contexts at session 1 is depicted in Fig. 4.26.

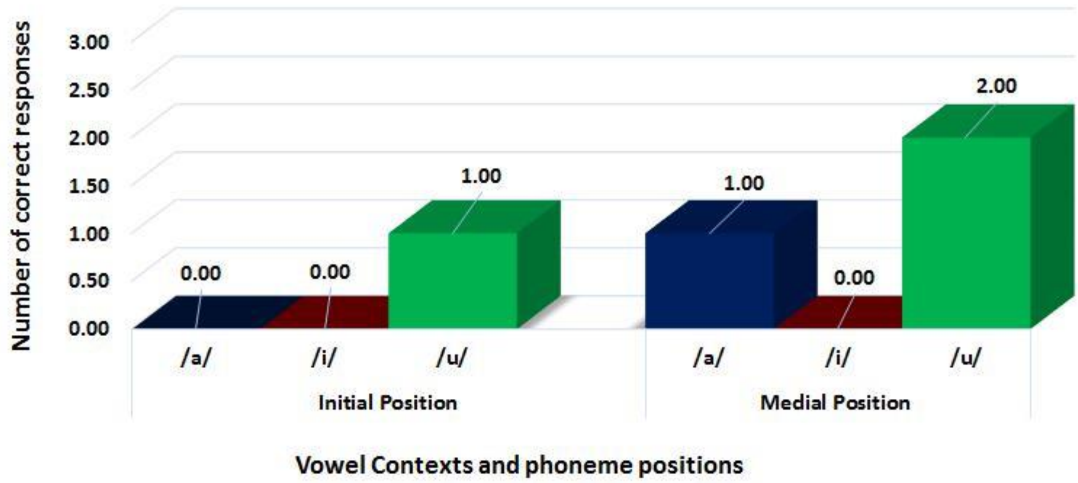
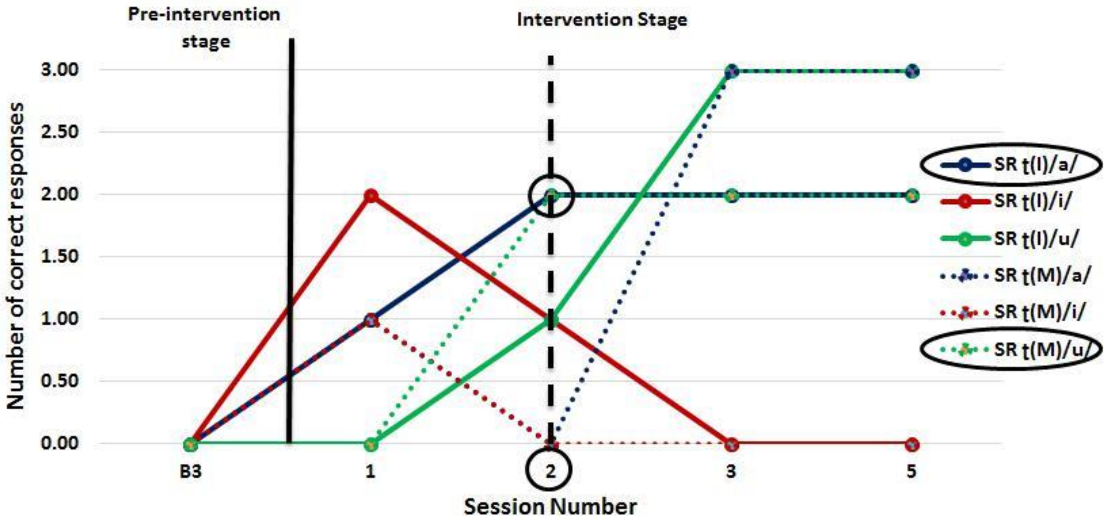


Figure 4.26. Number of correct responses (NCR) in each context at LSN-1 for SB

It is apparent from Fig. 4.26., that the NCR score is highest when retroflex /ʈ/ is in the medial position followed by vowel /u/.

Conclusion: The ***facilitating context*** was, target ***/ʈ/***in the medial position followed by vowel /u/ for ***SB***.

4) **Participant SR.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.27.*Number of correct responses (NCR) vs. sessions for unvoiced retroflex /ʈ/

Pre-intervention stage: No correct production of /ʈ/ during pre-intervention stage (Fig. 4.27).

Intervention stage:

- *Magnitude of behavior*: Contexts T(M)/u/ (e.g. /gu***ʈʈu***/) and T(I)/a/ (e.g. /***ʈa***garu/) have consistent 2/3 scores in three consecutive sessions(Fig. 4.27).
- *Latency of change in behavior*: By 2nd session a visible change in the behavior was observed for T(M)/u/ and T(I)/a/ (Fig. 4.27).

From Fig. 4.27, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.15.

Table 4.15.

Minimum number of sessions for acquiring the target phoneme /ʈ/ in different phonetic context for SR

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SR	2	6	3	3	5	2

IC- inconclusive due to high variability in performance

The least session number (LSN) in Table 4.15 is 2. The NCR scores for /ʈ/ in different contexts at session 2 is depicted in Fig. 4.28.

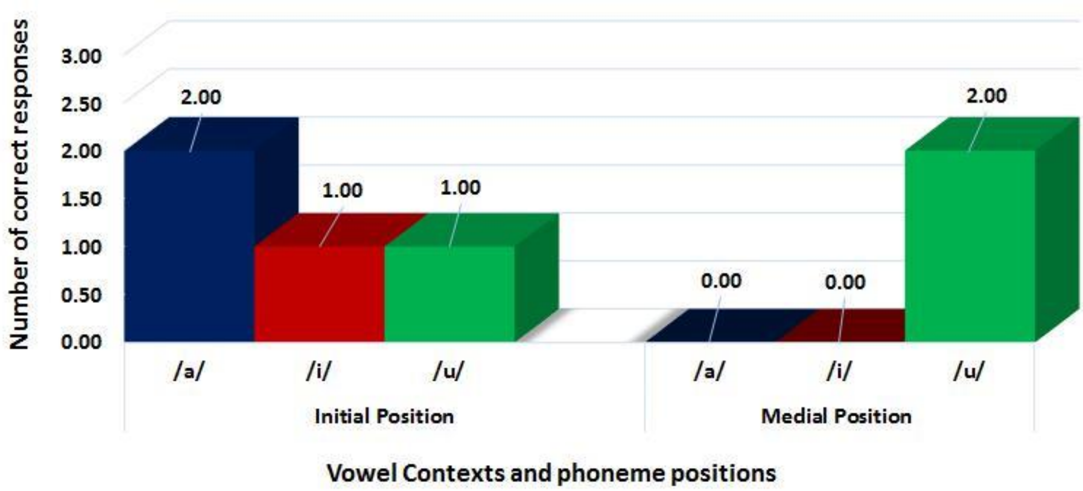
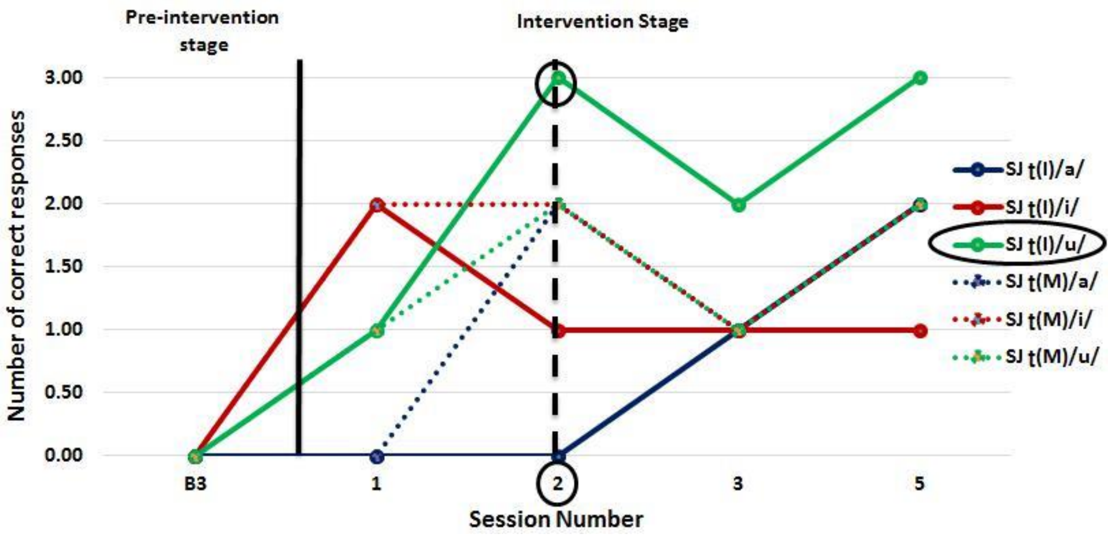


Figure 4.28. Number of correct responses (NCR) in each context at LSN-2 for SR

The NCR score is highest when retroflex /ʈ/ is in the medial position followed by vowel /u/ and when it is in the initial position followed by vowel /a/ (Fig. 4.28).

Conclusion: Unvoiced retroflex ***/ʈ/*** in ***the medial position followed by vowel /u/*** and /ʈ/ in the ***initial position followed by vowel /a/*** were the most facilitating contexts for ***SR***.

***5)* Participant SJ.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.29.*Number of correct responses (NCR) vs. sessions for unvoiced retroflex /ʈ/

Pre-intervention stage: There was no correct production of /ʈ/ during pre-intervention stage (Fig. 4.29).

Intervention stage:

- *Magnitude of behavior*: It is very evident that context T(I)/u/ (e.g. /***ʈu:***ru/) has the highest NCR scores (3/3 or 2/3)(Fig. 4.29).

- *Latency of change in behavior*: By 2nd session a greater change in the behavior was observed T(I)/u/ (Fig. 4.29).

From Fig. 4.29, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.16.

Table 4.16.

Minimum number of sessions for acquiring the target phoneme /ʈ/ in different phonetic context for SJ

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SJ	8	8	2	4	4	4

The least session number (LSN) in Table 4.16 is 2. The NCR scores for /ʈ/ in different contexts at session 2 is depicted in Fig. 4.30.

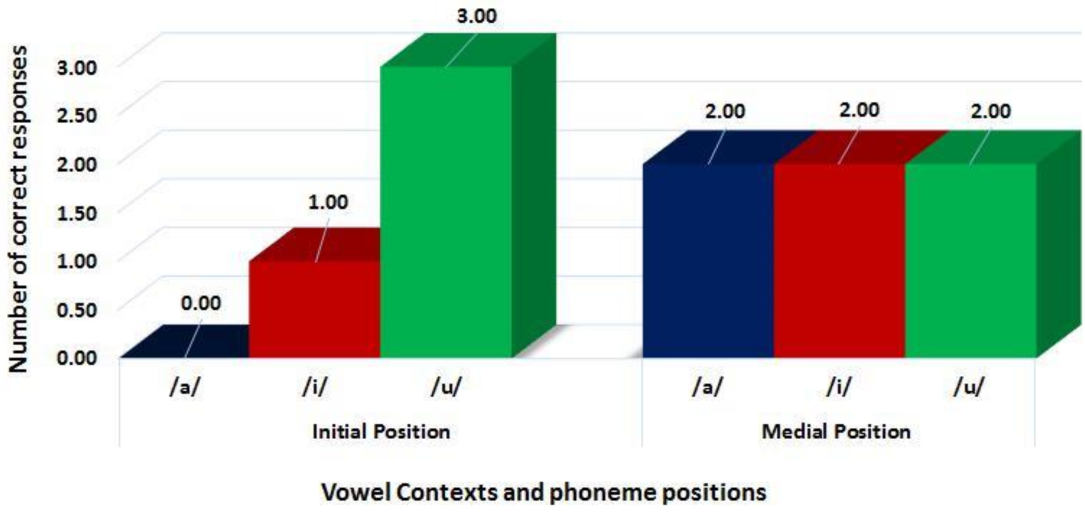


Figure 4.30. Number of correct responses (NCR) in each context at LSN-2 for SJ

The NCR score is highest when retroflex /ʈ/ is in the initial position followed by vowel /u/ (Fig. 4.30).

Conclusion: Unvoiced retroflex ***/ʈ/*** in the ***initial position followed by vowel /u/*** was the highly facilitating context for ***SJ***.

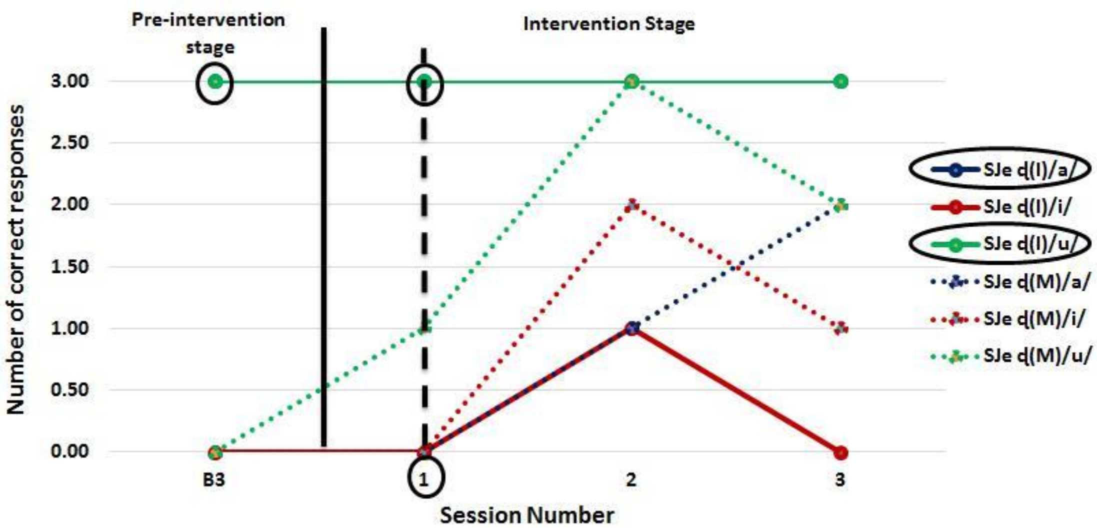
Vowel /u/ facilitated the production of unvoiced retroflex /ʈ/ in all the participants irrespective of phoneme position. This can be reasoned on the physiological basis of production of vowel /u/ where the protruded lips, the reduced distance between the tongue and the palate, and the upward movement of the whole tongue while producing /ʈu/ makes it easier to produce voiceless retroflex /ʈ/.

Another common feature observed was the more facilitating effect of medial position of the target retroflex than initial position. This can be due to the minimal influence by the articulatory requirements of adjacent sounds in medial position (Kent, 1982). Also, this result can be attributed to the syllable structure of the stimuli words considered. In the present study, the stimuli words for medial position constituted more target phonemes as geminated medial clusters which are relatively more stressed compared to singletons in the initial position. Perceptability of retroflexion is another major issue to consider which supports the results of the present study. The word coda retroflex are reliably identified compared to word onset retroflex (Steriade's, 2001). These results are also in consonance with the results of Shishira and Sreedevi (2013) and Sushma and Sreedevi (2013) reporting both initial and medial positions to facilitate the acquisition of retroflexes in typically developing children.

Physiological study by Irfana (2017) supports this result stating that retroflex are produced more effortlessly in the context of vowel /u/ than other vowels. On the other hand, these results are not in agreement with the report of Krishna and Manjula (1991) that vowels /a/ and /i/ are facilitating the production of unvoiced retroflex /ʈ/. These differences attribute to the age of the participants. Also, the second facilitating context for /ʈ/ was vowel /i/; attributed to the similarity in place of articulation. In the present study, vowel /a/ was the least facilitating context for all the retroflexes considered because the transition distance and duration of the tongue movement seems to be more in the context of the mid-low vowel /a/ compared to other two high vowels. In addition to the age factor, another significant contributing reason could be the sample size. Despite both being case studies, the former study had a single participant, and the current study included five participants for the target voiceless retroflex /ʈ/. Another contributing factor can be the difference in the measurements used. Krishna and Manjula (1991) considered acoustic measures, whereas the present study included behavioral measurements. Even intervention procedural variations in both the studies may have caused disagreement in results. In the present study, the target phonemes were taught at word level using phonetic placement approach whereas in Krishna and Manjula's study (1991), intervention involved a hierarchy of steps: auditory training and discrimination tasks followed by multisensory with phonetic placement approach in isolation followed by production of target in various contexts at non-word and word level.

4.4. Facilitating context for voiced retroflex /ɖ/ (5 participants)

1) **Participant SJe.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.31. Number of correct responses (NCR) vs. sessions for voiced retroflex /ɖ/

Pre-intervention stage: Voiced retroflex /ɖ/ had emerged in initial position of the word followed by vowel /u/ and vowel /a/ during pre-intervention stage itself (Fig. 4.31).

Intervention stage:

- *Magnitude of behavior*: It is very evident that contexts T(I)/u/ (e.g. /***ɖu***mmu/) and T(I)/a/ (e.g. /***ɖa***bbi/) have the highest NCR scores (3/3)in all the three consecutive sessions (Fig. 31).

- *Latency of change in behavior*: By 1st session itself, a noticeable change in the behavior was observed T(I)/u/ and T(I)/a/ (Fig. 4.31).

From Fig. 4.31, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.17.

Table 4.17.

Minimum number of sessions for acquiring the target phoneme /ɖ/ in different phonetic context for SJe

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SJe	1	4	1	3	4	2

The least session number (LSN) in Table 4.17 is 1. The NCR scores for /ɖ/ in different contexts at session 1 is depicted in Fig. 4.32.

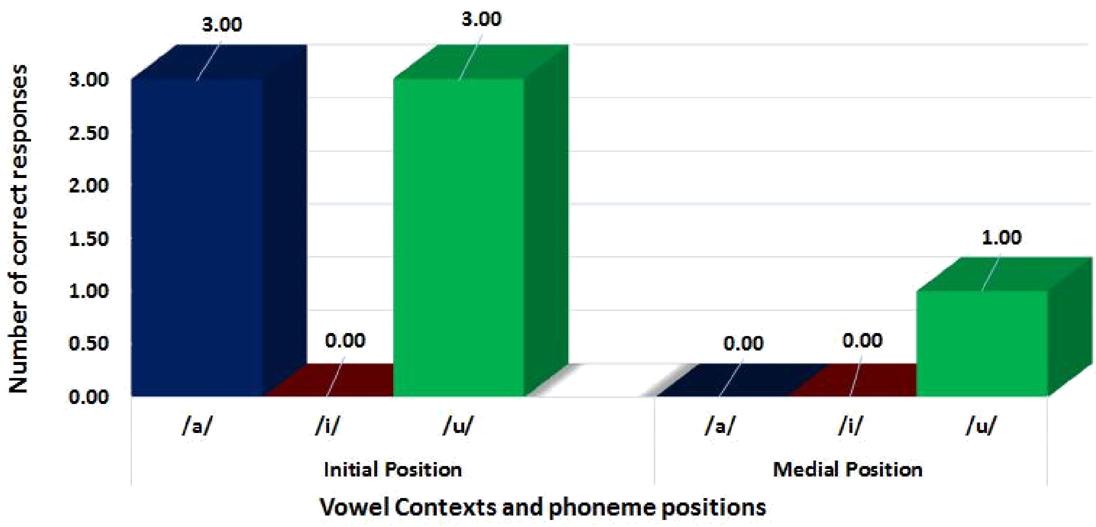
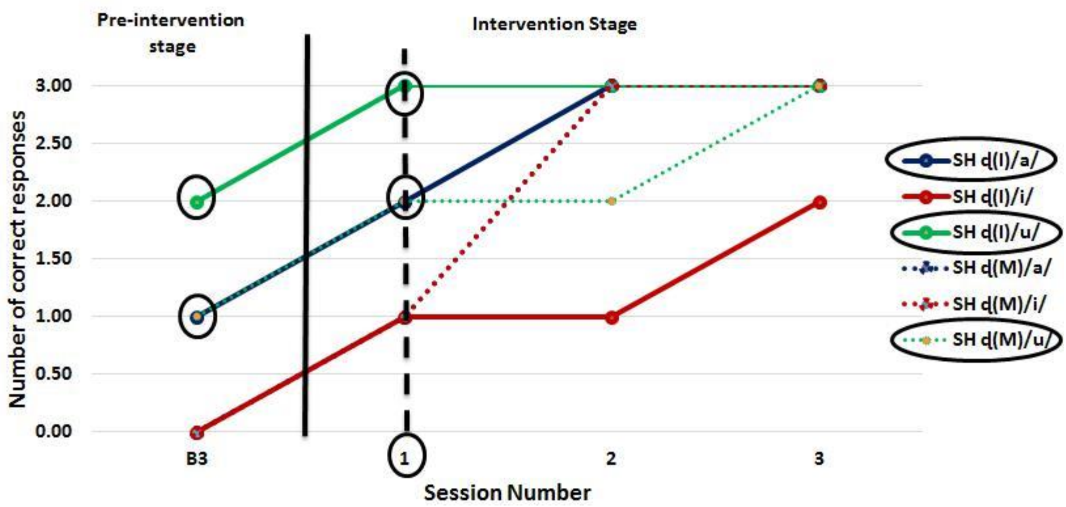


Figure 4.32. Number of correct responses (NCR) in each context at LSN-1 for SJe

The NCR score is highest when retroflex /ɖ/ is in the initial position followed by either vowel /u/ or /a/ (Fig. 4.32) for SJe.

Conclusion: It is evident that ***target /ɖ/ in the initial position*** followed by ***vowel /u/ and /ɖ/ in the initial position followed by vowel /a/ facilitated*** the production of ***voiced retroflex /ɖ/*** in ***SJe***.

2) Participant SH.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.33.*Number of correct responses (NCR) vs. sessions for voiced retroflex /ɖ/

Pre-intervention stage: Voiced retroflex /ɖ/ had emerged in initial position of the word followed by vowel /u/ during pre-intervention stage itself (Fig. 4.33).

Intervention stage:

- *Magnitude of behavior*: It is very evident that contexts T(I)/u/ (e.g. /***ɖu***mmu/), T(M)/u/ (e.g. /pa***ɖɖu***/) / and T(I)/a/ (e.g. /***ɖa***bbi/) have the highest NCR scores (3/3) in all the three consecutive sessions (Fig. 4.33).

- *Latency of change in behavior*: By 1st session a greater change in the behavior was observed T(I)/u/, T(M)/u/ and T(I)/a/ (Fig. 4.33).

From Fig. 4.33, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.18.

Table 4.18.

Minimum number of sessions for acquiring the target phoneme /ɖ/ in different phonetic context for SH

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SH	1	3	1	2	2	1

The least session number (LSN) in Table 4.18 is 1. The NCR scores for /ɖ/ in different contexts at session 1 is depicted in Fig. 4.34.

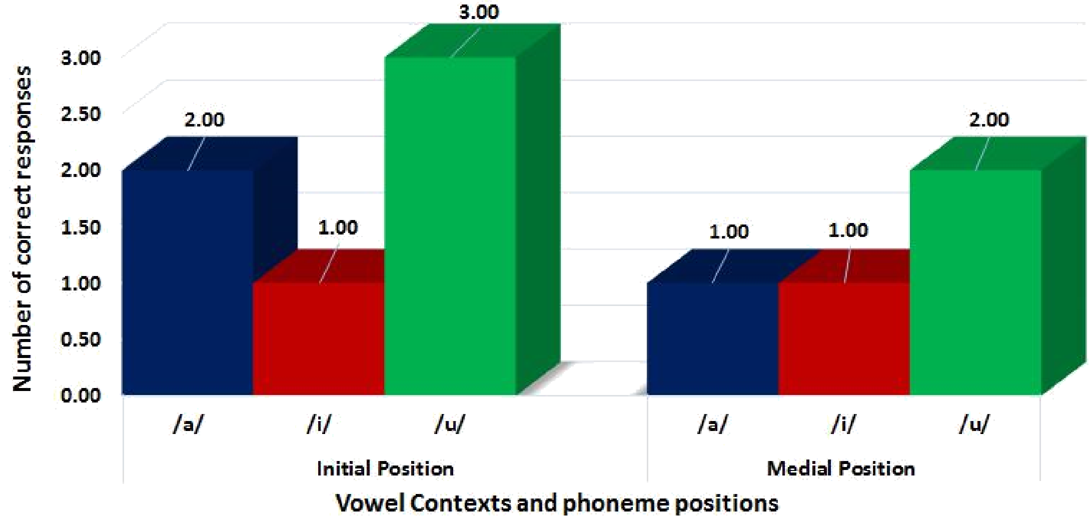
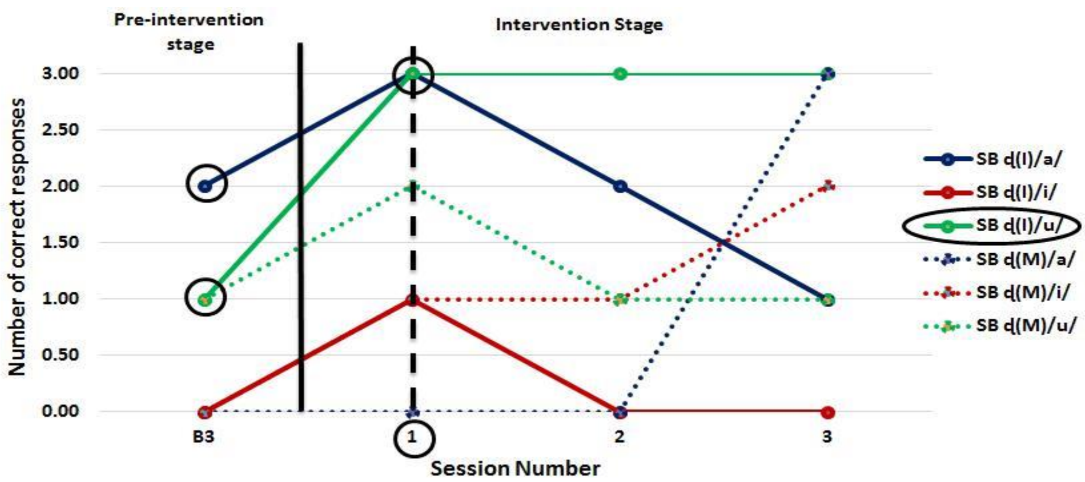


Figure 4.34. Number of correct responses (NCR) in each context at LSN-1 for SH

The NCR score is highest when retroflex /ɖ/ is in the initial position followed by either vowel /u/ or /a/ and in the medial position followed by vowel /u/ (Fig. 4.34) for SH.

Conclusion: Voiced retroflex ***/ɖ/*** in either ***initial or medial position followed by vowel /u/*** and in the ***initial position followed by vowel /a/*** were the most ***facilitating*** contexts for the production of /ɖ/ in ***SH*** similar to SJe.

3) Participant SB.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.35.*Number of correct responses (NCR) vs. sessions for voiced retroflex /ɖ/

Pre-intervention stage: The voiced retroflex /ɖ/ emerged in the contexts of T(I)/a/ (e.g. /*ɖa*bbi/), T(I)/u/ (e.g. /***ɖu***mmu/), T(M)/i/ (e.g. /maɳ***ɖi***/), and T(M)/u/ (e.g. /gaɳ***ɖa***su/) during pre-intervention phase (Fig. 4.35).

Intervention stage:

- *Magnitude of behavior*: It is very evident that contexts T(I)/u/ (e.g. /***ɖu***mmu/), has the highest NCR scores (3/3)in all the three consecutive sessions (Fig. 4.35).

- *Latency of change in behavior*: By 1st session a larger change in the behavior was observed T(I)/u/ (Fig. 4.35).

From Fig. 4.35, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.19.

Table 4.19.

Minimum number of sessions for acquiring the target phoneme /ɖ/ in different phonetic context for SB

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SB	IC	IC	1	IC	IC	IC

IC-inconclusive due to high variability in performance

The least session number (LSN) in Table 4.19 is 1. The NCR scores for /ɖ/ in different contexts at session 1 is depicted in Fig. 4.36.

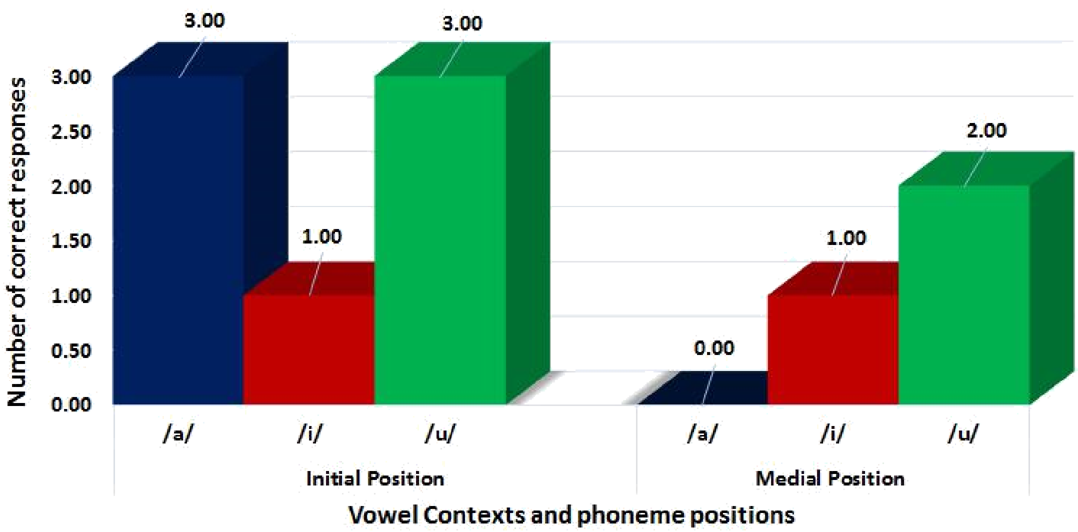
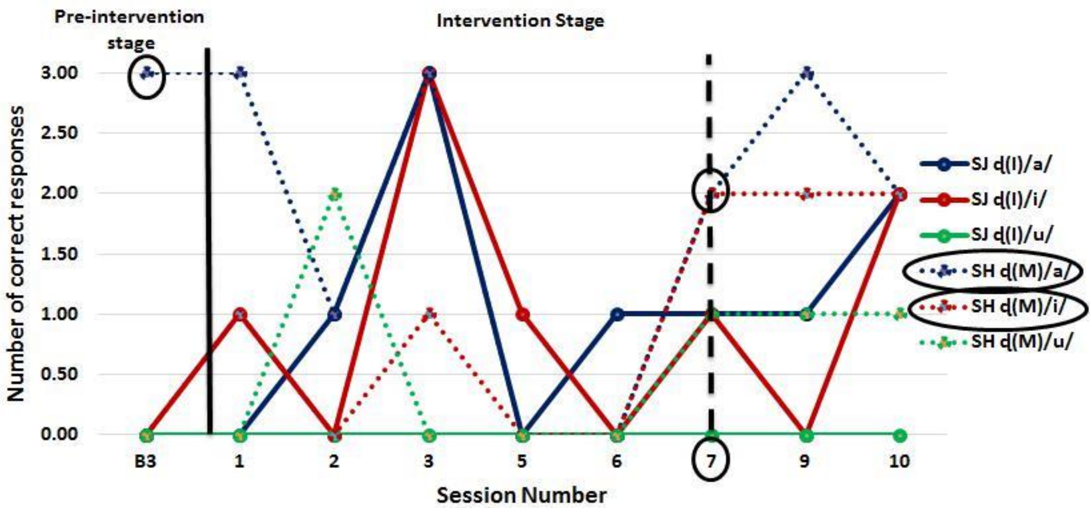


Figure 4.36. Number of correct responses (NCR) in each context at LSN-1 for SB

The NCR score is highest when retroflex /ɖ/ is in the initial position followed by either vowel /u/ or /a/ and in the medial position followed by vowel /u/ (Fig. 4.36) but the scores are retained only in the context of T(I)/u/ (Fig. 4.33) for SB.

Conclusion: The ***facilitating context*** for the correct production of ***/ɖ/*** in ***SB*** was ***/ɖ/ in the initial position followed by vowel /u/***.

4) Participant SJ.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.37. Number of correct responses (NCR) vs. sessions for voiced retroflex /ɖ/

Pre-intervention stage: The phoneme /ɖ/ emerged in the context of T(M)/a/ (e.g. /gaɳ***ɖa***su/) at B3 (Fig. 4.37).

Intervention stage:

- *Magnitude of behavior*: SJ obtained higher scores was in the contexts of T(M)/a/ (e.g. /gaɳ***ɖa***su/) followed by T(M)/i/ (e.g. /maɳ***ɖi***/) (Fig. 4.37).

- *Latency of change in behavior*: By 7^{th} session a greater change in the behavior was observed T(M)/a/ and T(M)I (Fig. 4.37).

From Fig. 4.37, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.20.

Table 4.20.

Minimum number of sessions for acquiring the target phoneme /ɖ/ in different phonetic context for SJ

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SJ	10	10	IC	6	6	10

IC-inconclusive due to high variability in performance

The least session number (LSN) in Table 4.20 is 6. The NCR scores for /ɖ/ in different contexts at intervention session 6 is depicted in Fig. 4.38.

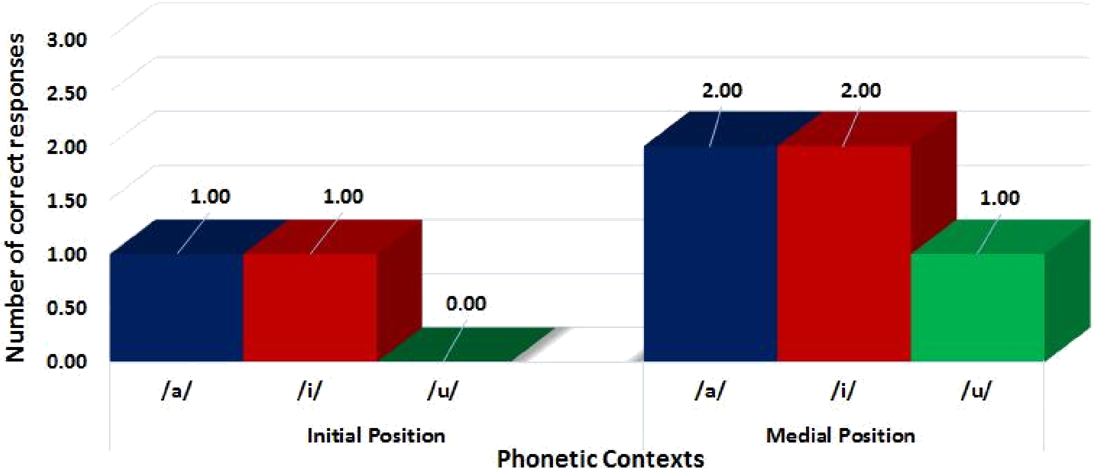
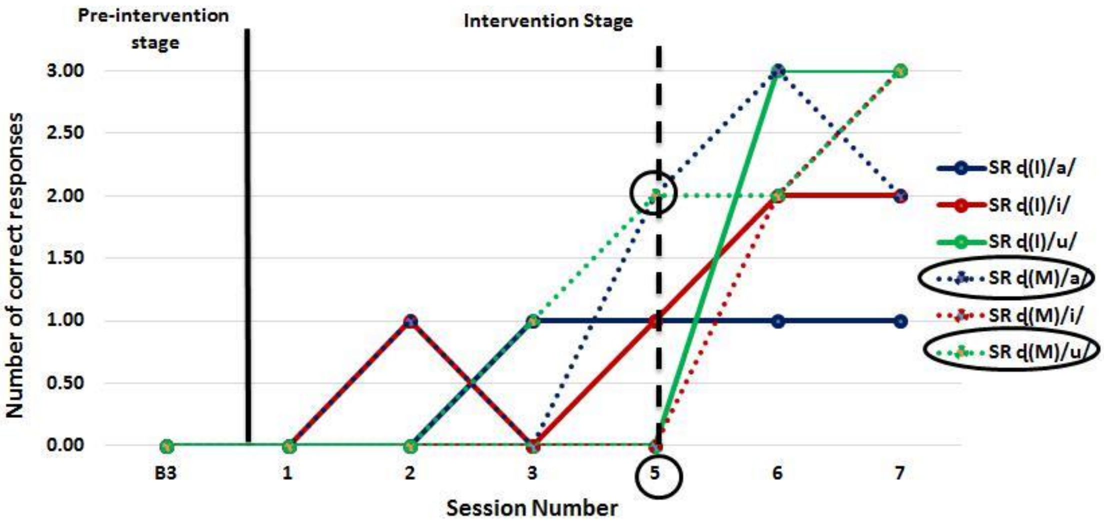


Figure 4.38. Number of correct responses (NCR) in each context at LSN-6 for SJ

The NCR score is highest when retroflex /ɖ/ is in the medial position followed by either vowel /i/ or /a/ (Fig. 4.38) for SJ.

Conclusion: The highly ***facilitating context*** was when ***/ɖ/*** was in ***medial position followed by either vowel /i/ or /a/ in SJ***.

5) Participant SR.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ○; most facilitating context/s - ⬭ }

*Figure 4.39.*Number of correct responses (NCR) vs. sessions for voiced retroflex /ɖ/

Pre-intervention stage: There was consistent error production (0%) of the target /ɖ/ (Fig. 4.39).

Intervention stage:

- *Magnitude of behavior*: Highest scores obtained in the contexts of T(M)/u/ (e.g. /pa***ɖɖu***/) and T(M)/a/ (e.g. /gaɳ***ɖa***su/) (Fig. 4.39).

- *Latency of change in behavior*: By 4th intervention session a greater change in the behavior was observed T(M)/a/ and T(M)/u/ (Fig. 4.39).

From Fig. 4.39, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.21.

Table 4.21.

Minimum number of sessions for acquiring the target phoneme /ɖ/ in different phonetic context for SR

Participant	**T(I)/a/**	**T(I)/i/**	**T(I)/u/I**	**T(M)/a/**	**T(M)/i/**	**T(M)/u/**
SR	8	5	5	4	5	4

IC-inconclusive due to high variability in performance

The least session number (LSN) in Table 4.21 is 4. The NCR scores for /ɖ/ in different contexts at intervention session 6 is depicted in Fig. 4.40.

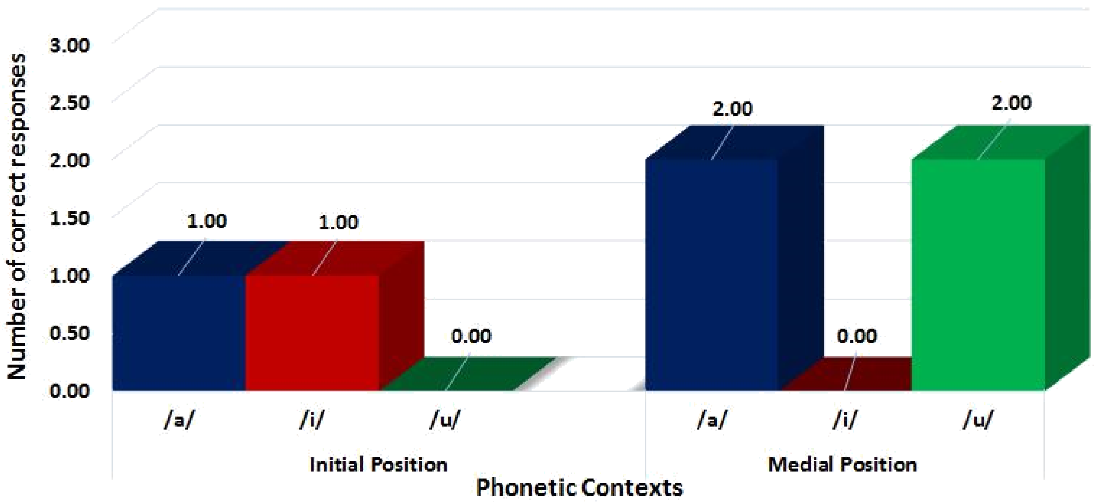


Figure 4.40. Number of correct responses (NCR) in each context at LSN-4 for SR

The NCR score is highest when retroflex /ɖ/ is in the medial position followed by either vowel /u/ or /a/ (Fig. 4.40) for SR.

Conclusion: Voiced retroflex ***/ɖ/*** in the ***medial position followed by either vowel /u/ or /a/*** highly ***facilitated*** the production of /ɖ/ in ***SR***.

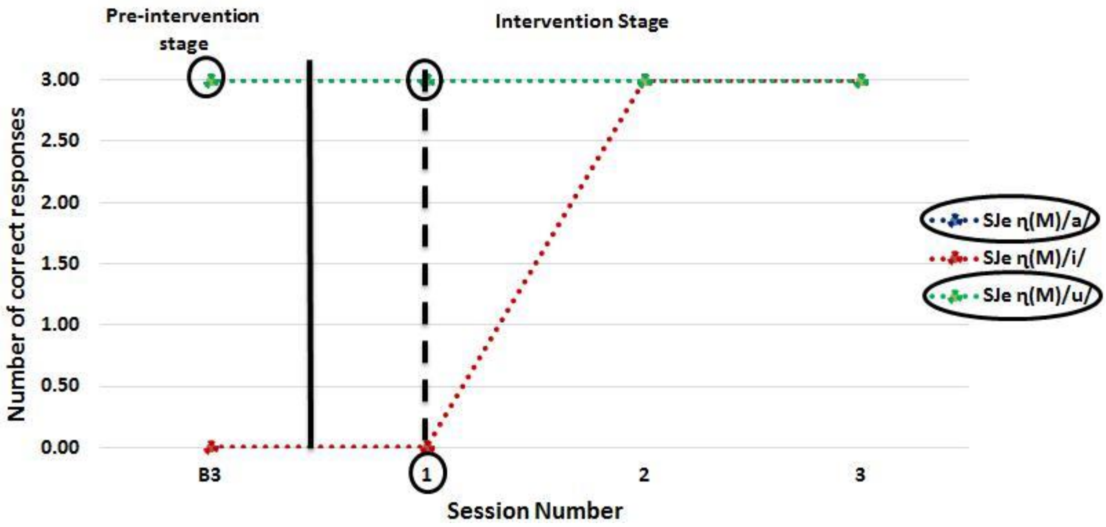
Voiced retroflex /ɖ/ in the initial position followed by vowel /u/ had higher correct production in SJe, SH, and SB and in the initial position followed by vowel /a/ in SJe and SH. This can be attributed to the R-L coarticulatory effect of voiced consonants in the adjacent syllable of the target words (e.g. /***ɖa***bbi/). The coarticulatory studies report that voicing nature of a consonant is observed in the syllable preceding it and Bleile (1996) supporting this reports that voiced consonants are easily produced when present in the beginning of the syllable or word. In contrast, /ɖ/ in the medial position followed by vowel /a/ facilitated the production in SJ and SR. This difference in facilitating phoneme position can be probably due to the presence of voicing errors and mild-moderate severity of the articulatory problem in SJ and SR. This can be because it was easy to make the minimal articulatory adjustments with adjacent sounds in medial position for SJ and SR as reported by Kent(1982). Also, this result can be attributed to the syllable structure of the stimuli words considered. In the present study the stimuli words for medial position context constituted target phonemes more as geminated medial clusters which are relatively more stressed compared to singletons in the initial position. Perceptually word coda retroflex are reliably identified compared to word onset retroflex (Steriade's, 2001). These results are in consonance with the results of Shishira and Sreedevi (2013) and Sushma and Sreedevi (2013) that both initial and medial position facilitates the acquisition of retroflexes.

Vowel /a/ has consistently facilitated the production of voiced retroflex /ɖ/ in almost all the participants. Kalaiah and Bhat (2017) provided perceptual support to the finding stating that retroflex sounds are poorly perceived in the high vowel context than low vowel context. This result is not in agreement with physiological basis of Irfana (2017) that vowel /u/ facilitates retroflex production. The context, target in the initial position followed by vowel /u/ also facilitated the production of /ɖ/ but, due to only one stimulus, it is difficult to comment on its facilitatory characteristics clearly.

4.5. Facilitating context for nasal retroflex /ɳ/ (8 participants)

Nasal retroflex /ɳ/ occurs only in the medial position as per the phonotactics of Kannada. Therefore the facilitating vowel contexts are highlighted in the following section.

1) Participant SJe.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.41.*Number of correct responses (NCR) vs. sessions for nasal retroflex /ɳ/ *Pre-intervention stage:* Nasal retroflex /ɳ/ emerged in the vowel contexts /a/ and /u at B3 (Fig. 4.41). This may be due to prior knowledge on place of articulation of retroflex.

Intervention stage:

- *Magnitude of behavior*: Highest scores obtained in the contexts of T(M)/u/ (e.g. /ka***ɳɳu***/) and T(M)/a/ (e.g. /ba***ɳɳa*** /) (Fig. 4.41).

- *Latency of change in behavior*: By B3 itself a notable change in the behavior was observed T(M)/a/ and T(M)/u/ (Fig. 4.41).

From Fig. 4.41, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.22.

Table 4.22.

Minimum number of sessions for acquiring the target phoneme /ɳ/ in different phonetic context for SJe

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SJe	-	-	-	1	2	1

The least session number (LSN) in Table 4.22 is 1. The NCR scores for /ɳ/ in different contexts at session 1 is depicted in Fig. 4.42.

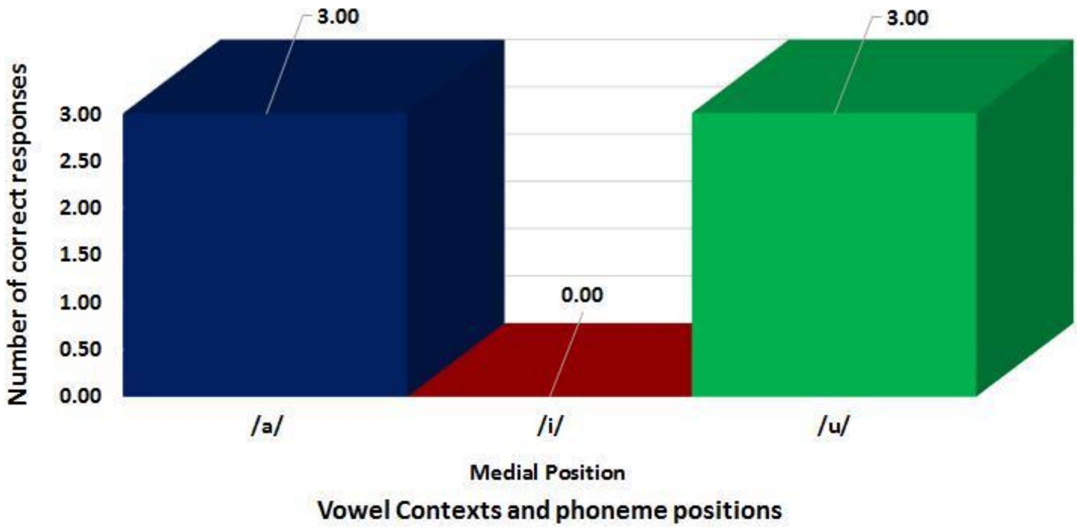
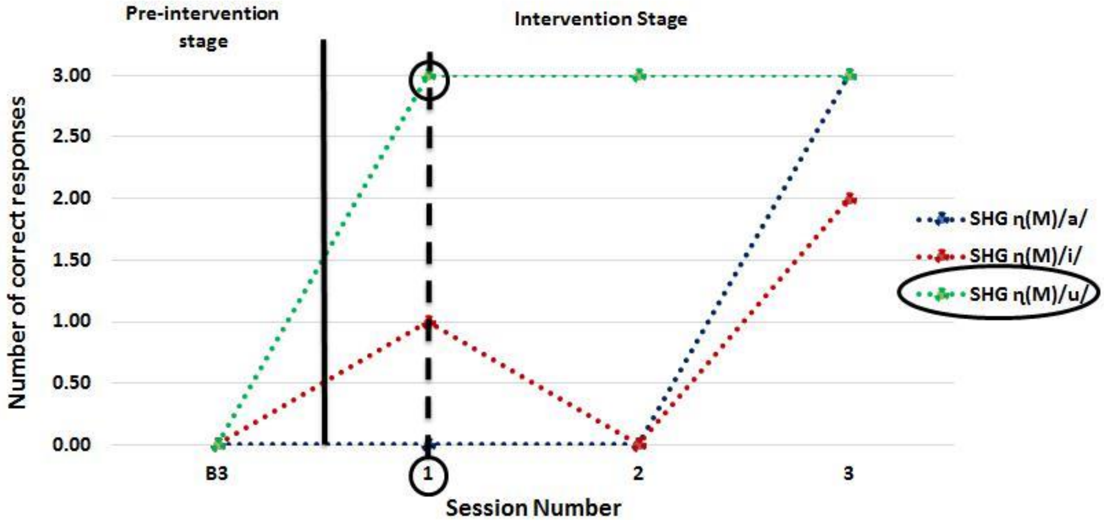


Figure 4.42. Number of correct responses (NCR) in each context at LSN-1 for SJe The

NCR score is highest in the context of vowel /u/ and /a/ (Fig. 4.42) for SJe.

Conclusion: Vowels /u/ and /a/ facilitated the production of /ɳ/ more than /i/ in SJe.

2) **Participant SHG.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ; most facilitating context/s - }

*Figure 4.43.*Number of correct responses (NCR) vs. sessions for nasal retroflex /ɳ/

Pre-intervention stage: No production of nasal retroflex /ɳ/ at B3 (Fig. 4.43).

Intervention stage:

- *Magnitude of behavior*: It is evident from Fig. 4.43, that vowel /u/ (e.g. /ka***ɳɳu***/) highly facilitated the production of /ɳ/.

- *Latency of change in behavior*: At 1st session itself a prominent change in the behavior was observed T(M)/u/ (Fig. 4.43).

From Fig. 4.43, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.23.

Table 4.23.

Minimum number of sessions for acquiring the target phoneme /ɳ/ in different phonetic context for SHG

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SHG	-	-	-	3	3	1

The least session number (LSN) in Table 4.23 is 1. The NCR scores for /ɳ/ in different contexts at session 1 is depicted in Fig. 4.44.

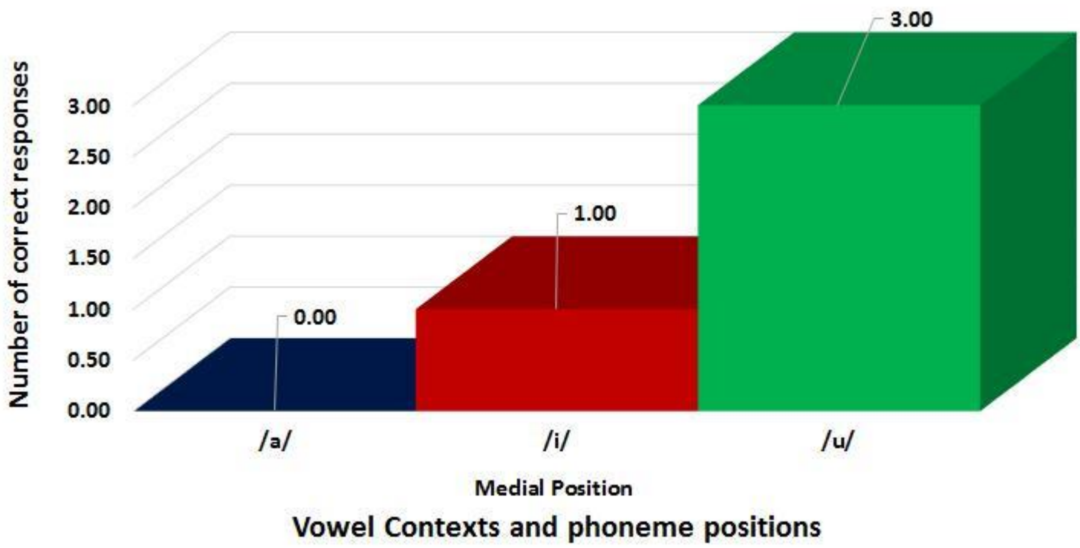
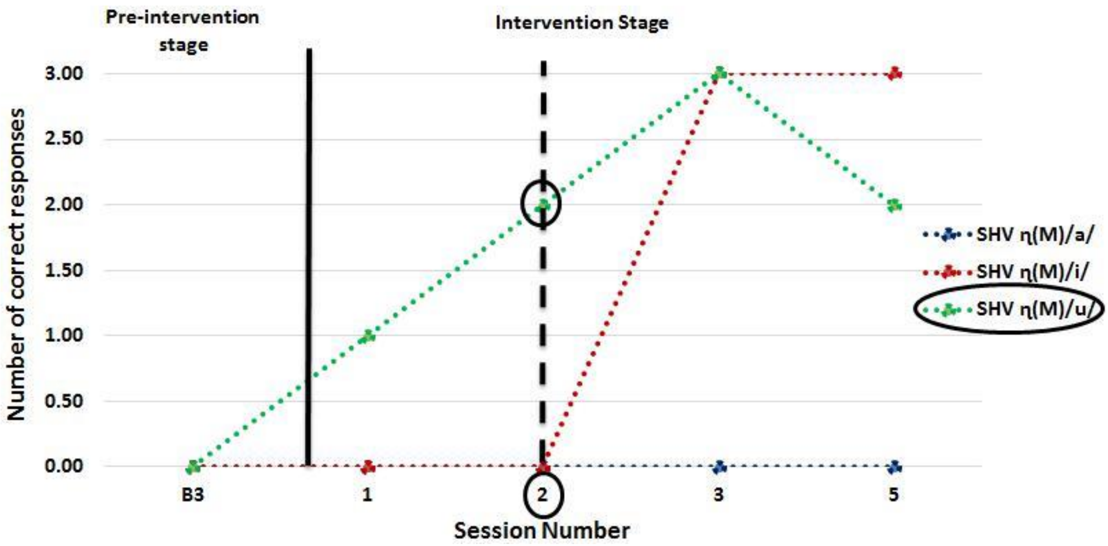


Figure 4.44. Number of correct responses (NCR) in each context at LSN-1 for SHG

From Fig. 4.44 it is apparent that the NCR score is highest in the context of vowel /u/ for SHG.

Conclusion: ***Vowel /u/*** highly ***facilitated*** the production of ***/ɳ/*** in ***SHG*** similar to SJe.

3) Participant SHV.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.45.*Number of correct responses (NCR)vs. sessions fornasal retroflex /ɳ/

Pre-intervention stage: No correct production of nasal retroflex /ɳ/ at B3 (Fig. 4.45).

Intervention stage:

- *Magnitude of behavior*: It is evident from Fig. 4.45, that vowel /u/ (e.g. /ka***ɳɳu***/) highly facilitated the production of /ɳ/.

- *Latency of change in behavior*: At 2nd session a greater change in the behavior was observed T(M)/u/ (Fig. 4.45).

From Fig. 4.45, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.24.

Table 4.24.

Minimum number of sessions for acquiring the target phoneme /ɳ/ in different phonetic context for SHV

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SHV	-	-	-	>3	3	2

The least session number (LSN) in Table 4.24 is 2. The NCR scores for /ɳ/ in different contexts at session 2 is depicted in Fig. 4.46.

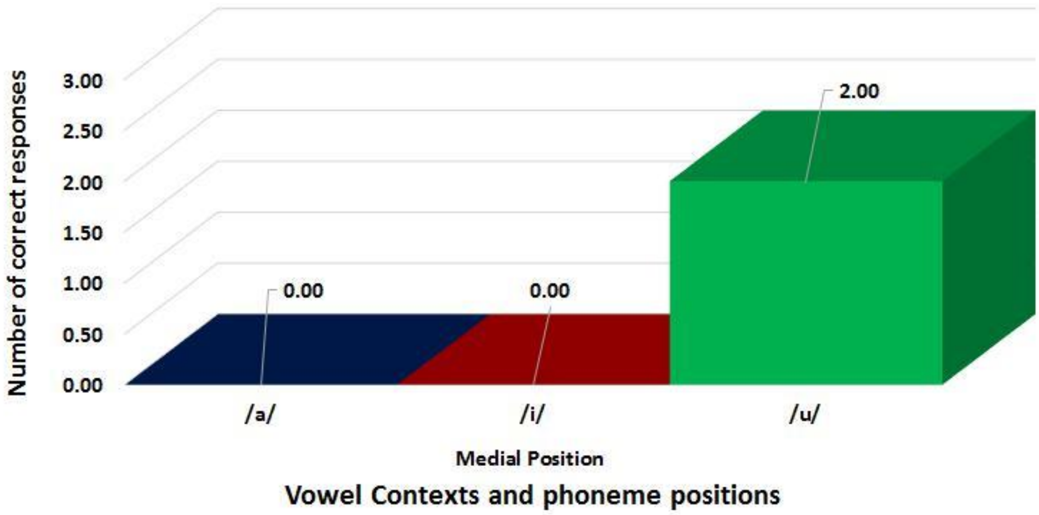
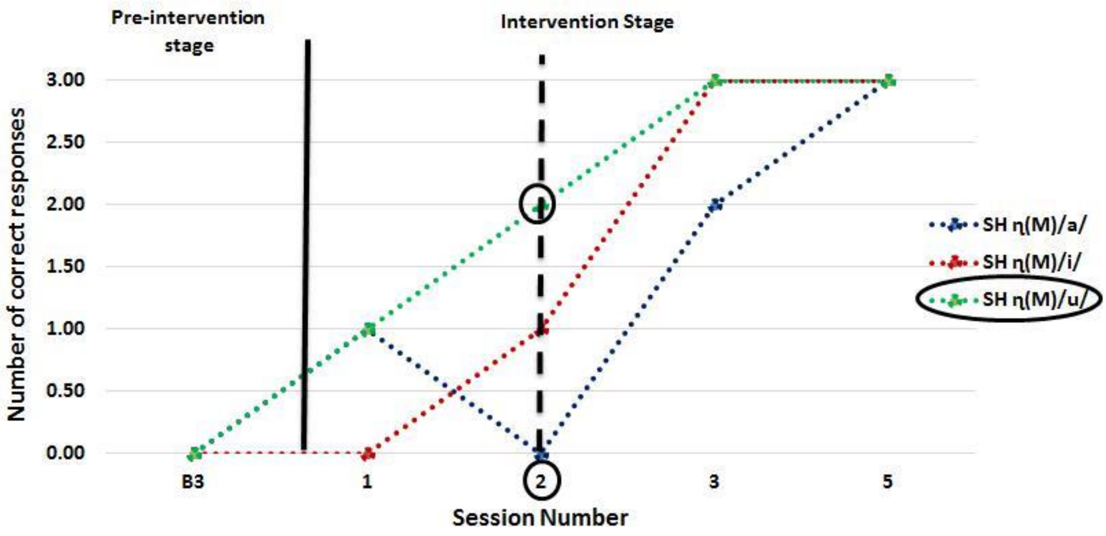


Figure 4.46. Number of correct responses (NCR) in each context at LSN-2 for SHV

From Fig. 4.46 it is apparent that the NCR score is highest in the context of vowel /u/ for SHV.

Conclusion: Similar to SJe and SHG, ***vowel /u/*** was the ***highly facilitating context*** for the production of ***/ɳ/*** in ***SHV*** as well.

4) **Participant SH.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.47.*Number of correct responses (NCR) vs. sessions for nasal retroflex /ɳ/

Pre-intervention stage: No production of nasal retroflex /ɳ/ at B3 (Fig. 4.47).

Intervention stage:

- *Magnitude of behavior*: It is evident fromFig. 4.47, that vowel /u/ (e.g. /ka***ɳɳu***/) highly facilitated the production of /ɳ/.

- *Latency of change in behavior*: At 2nd session an observable change in the behavior was present for T(M)/u/ (Fig. 4.47).

From Fig. 4.47, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts for /ɳ/ is provided in Table 4.25.

Table 4.25

Minimum number of sessions for acquiring the target phoneme /ɳ/ in different phonetic contexts for SH

Participant	**T(I)/a/**	**T(I)/i/**	**T(I)/u/I**	**T(M)/a/**	**T(M)/i/**	**T(M)/u/**
SH	-	-	-	3	3	2

The least session number (LSN) in Table 4.25 is 2. The NCR scores for /ɳ/ in different contexts at session 2 is depicted in Fig. 4.48.

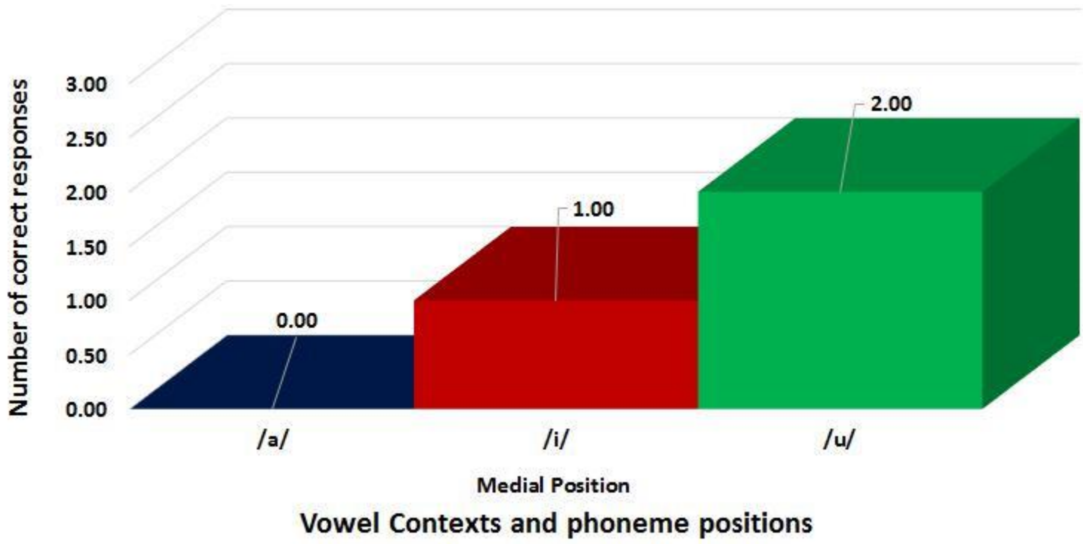
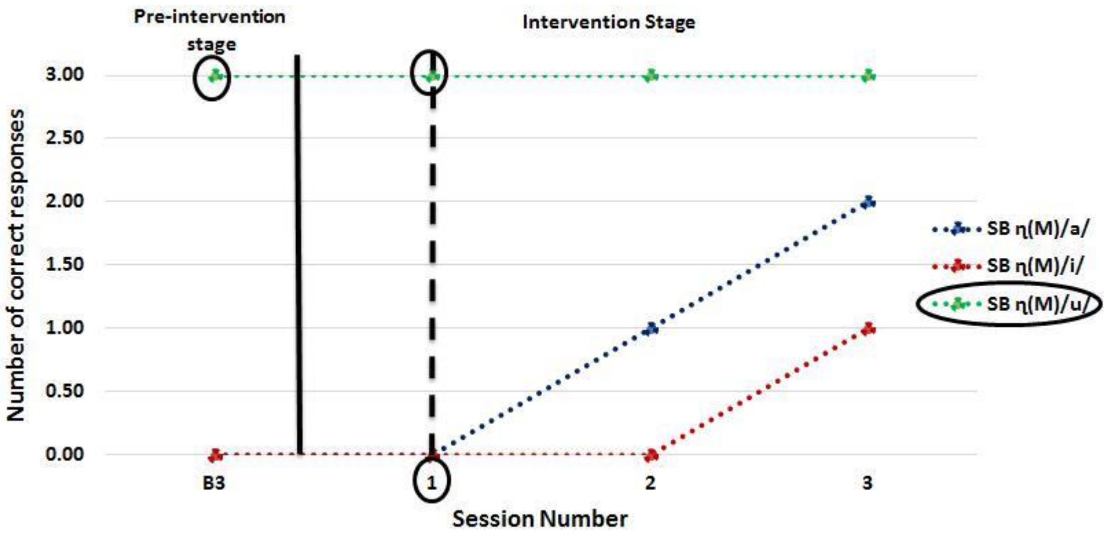


Figure 4.48. Number of correct responses (NCR) in each context at LSN-2 for SH

From Fig. 4.48 it is evident that highest score is in the context of vowel /u/ for SH.

Conclusion: The vowel context /u/ following the target /ɳ/, ***T(M)/u/ (e.g. /*****ha*****ɳɳu/)***highly facilitated the ***nasal retroflex*** in ***SH*** similar to SJe, SHG, and SHV.

5) Participant SB.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.49.*Number of correct responses (NCR) vs. sessions for nasal retroflex /ɳ/

Pre-intervention stage: Nasal retroflex /ɳ/ emerged in the vowel context /u/ at B3 (Fig. 4.49).

Intervention stage:

- *Magnitude of behavior*: It is evident fromFig. 4.49, that vowel /u/ (e.g. /ka***ɳɳu***/) highly facilitated the production of /ɳ/.
- *Latency of change in behavior*: At B3 itself, the facilitating effect of vowel /u/ was apparent (Fig. 4.49).

From Fig. 4.49, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts for /ɳ/ is provided in Table 4.26.

Table 4.26

Minimum number of sessions for acquiring the target phoneme /ɳ/ in different phonetic context for SB

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SB	-	-	-	IC	IC	1

IC-inconclusive

The least session number (LSN) in Table 4.26 is 1. The NCR scores for /ɳ/ in different contexts at session 1 is depicted in Fig. 4.50.

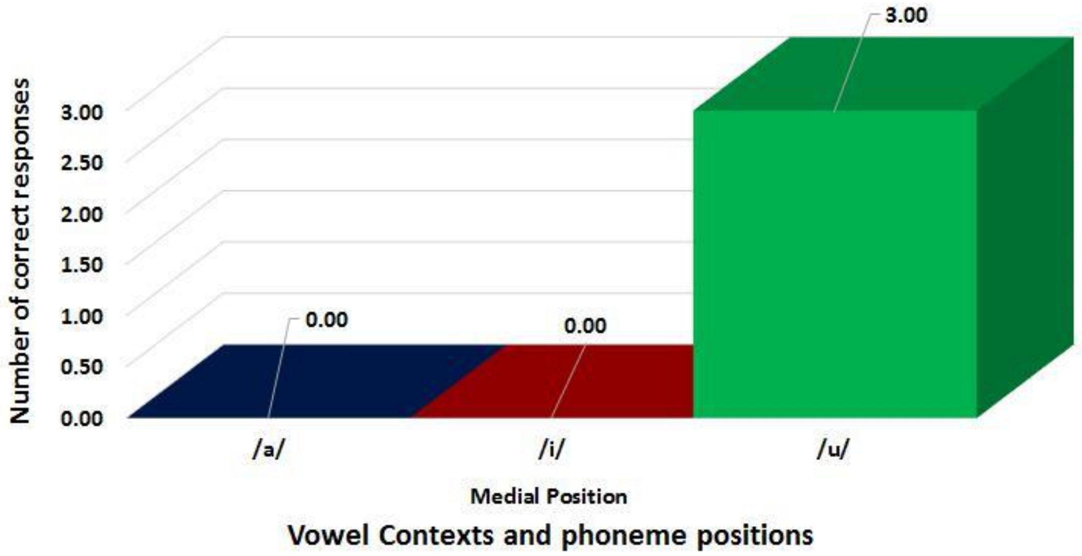
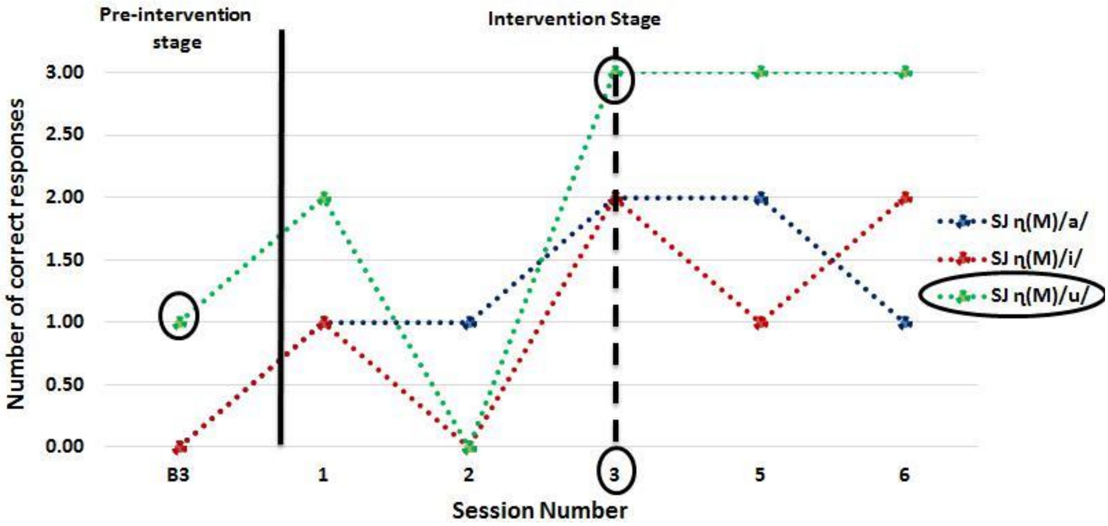


Figure 4.50. Number of correct responses (NCR) in each context at LSN-1 for SB

From Fig. 4.50 it is obvious that highest score is in the context of vowel /u/ for SB.

Conclusion: ***Vowel /u/*** had a definite ***facilitating effect*** for ***SB*** also similar to SJe, SHG, SHV, and SH.

6) Participant SJ.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.51.*Number of correct responses (NCR) vs. sessions for nasal retroflex /ɳ/

Pre-intervention stage: Nasal retroflex /ɳ/ is emerging in the vowel context /u/ at B3 (Fig. 4.51).

Intervention stage:

- *Magnitude of behavior*: It is again evident fromFig. 4.51, that vowel /u/ (e.g. /ka***ɳɳu***/) highly facilitating the production of /ɳ/.

- *Latency of change in behavior*: At 3rd session a greater change in correct production of /ɳ/ was observed in the context of vowel /u/ (Fig. 4.51).

From Fig. 4.51, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is for /ɳ/ is provided in Table 4.27.

Table 4.27

Minimum number of sessions for acquiring the target phoneme /ɳ/ in different phonetic context for SJ

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SJ	-	-	-	9	8	3

The least session number (LSN) in Table 4.27 is 3. The NCR scores for /ɳ/ in different contexts at session 3 is depicted in Fig. 4.52.

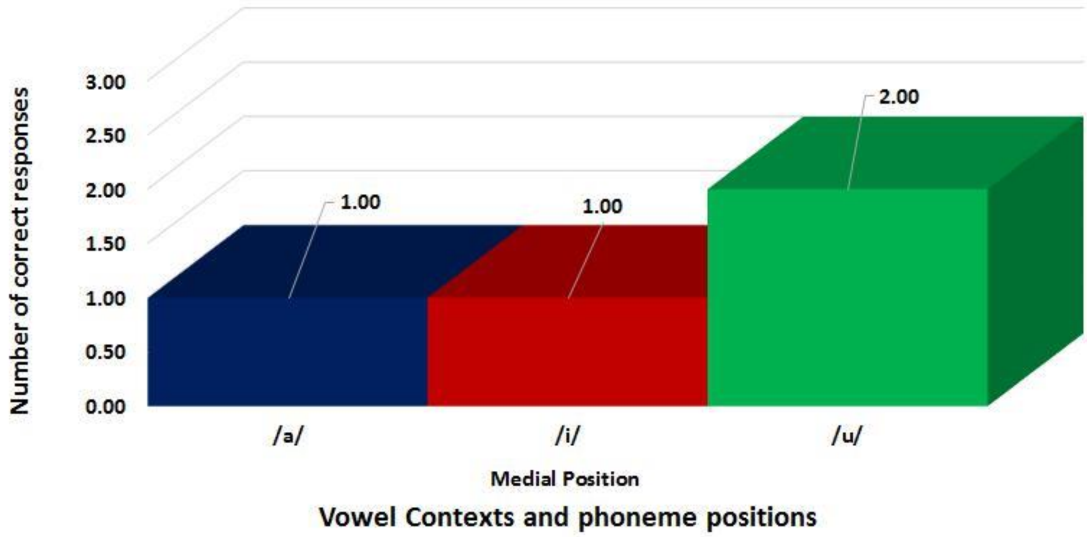
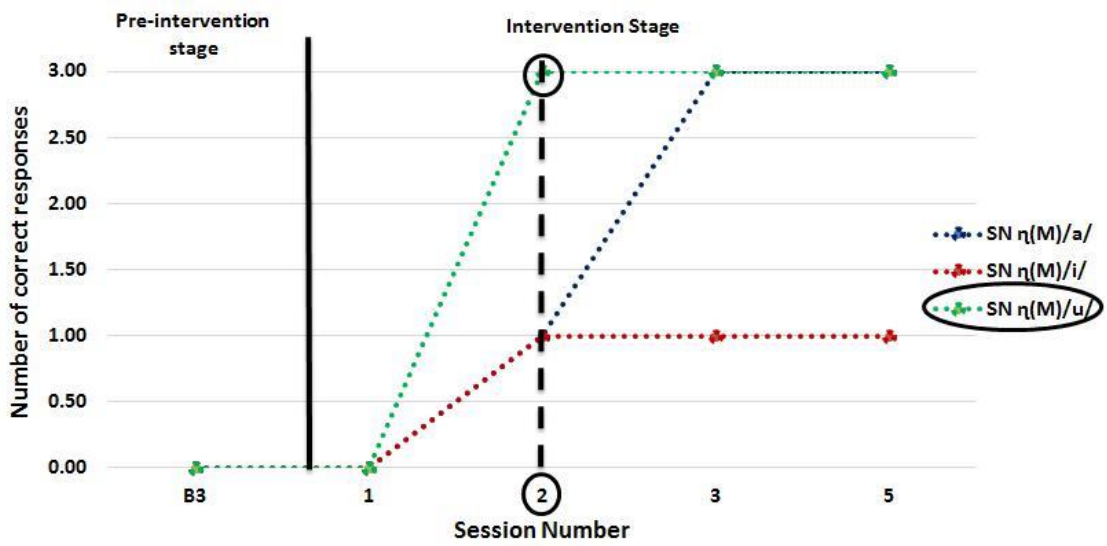


Figure 4.52. Number of correct responses (NCR) in each context at LSN-1 for SJ

From Fig. 4.52 it is evident that highest score is in the context of vowel /u/ for SJ also.

Conclusion: Vowel /u/ as in ***T(M)/u/ (e.g. /*****haɳɳu*****/) highly facilitated*** the production of ***nasal retroflex*** similar to SJe, SHG, SHV, SH, and SB.

7) Participant SN.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.53.*Number of correct responses (NCR) vs. sessions for nasal retroflex /ɳ/

Pre-intervention stage: No production of nasal retroflex /ɳ/ at B3 (Fig. 4.53).

Intervention stage:

Magnitude of behavior: It is over again evident from Fig. 4.53, that vowel /u/ (e.g. /ka***ɳɳu***/) is highly facilitating the production of /ɳ/.

- *Latency of change in behavior*: At 2nd session a greater change in correct production of /ɳ/ was observed in the context of vowel /u/ (Fig. 4.53).

From Fig. 4.53, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts for /ɳ/ is provided in Table 4.28.

Table 4.28

Minimum number of sessions for acquiring the target phoneme /ɳ/ in different phonetic context for SN

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SN	-	-	-	3	5	2

The least session number (LSN) in Table 4.28 is 2. The NCR scores for /ɳ/ in different contexts at session 2 is depicted in Fig. 4.54.

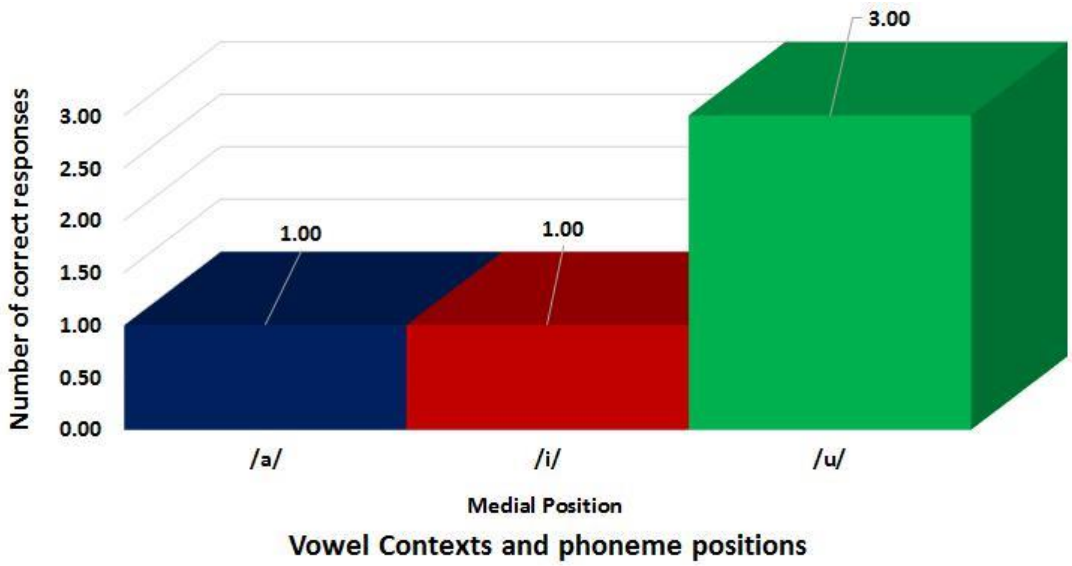
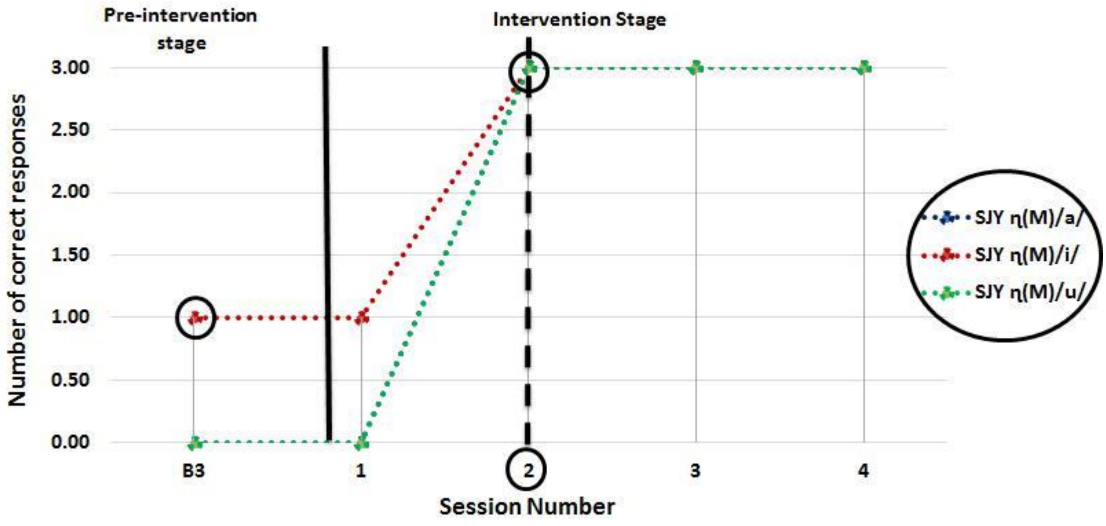


Figure 4.54. Number of correct responses (NCR) in each context at LSN-2 for SN

From Fig. 4.54 it is evident that highest score is in the context of vowel /u/ for SN as well.

Conclusion: The ***highly facilitating context*** for the production of ***nasal retroflex*** was vowel /u/, ***T(M)/u/ (e.g. /haɳɳu/)*** for ***SN*** .

8) Participant SJY.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.55.*Number of correct responses (NCR) vs. sessions for nasal retroflex /ɳ/

Pre-intervention stage: Nasal retroflex /ɳ/ emerging in the context of vowel /i/ at B3 (Fig. 4.55).

Intervention stage:

- *Magnitude of behavior*: It is again evident from Fig. 4.55, that vowel /i/ (e.g. /ma***ɳi***/) is highly facilitating the production of /ɳ/ followed by vowel /a/ (e.g. /ba***ɳɳa***/) and /u/ (e.g. /ka***ɳɳu***/).

- *Latency of change in behavior*: At 2nd session a greater change in correct production of /ɳ/ was observed in all three vowel contexts (Fig. 4.55).

From Fig. 4.55, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.29.

Table 4.29

Minimum number of sessions for acquiring the target phoneme /ɳ/ in different phonetic context for SJY

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SJY	-	-	-	2	2	2

The least session number (LSN) in Table 4.29 is 2. The NCR scores for /ɳ/ in different contexts at session 2 is depicted in Fig. 4.56.

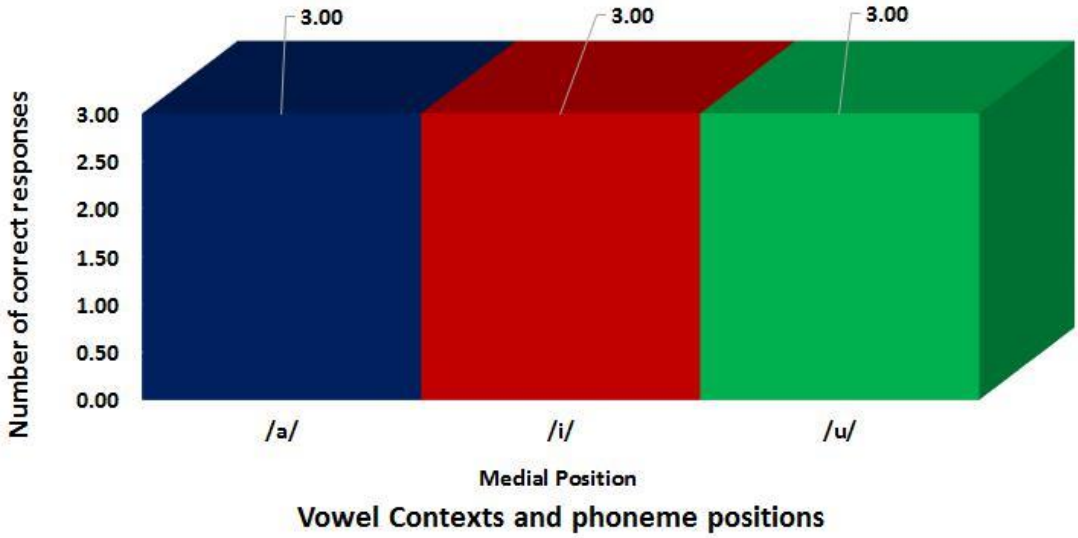


Figure 4.56. Number of correct responses (NCR) in each context at LSN-2 for SJY From

Fig. 4.56 it is evident NCR scores are maximum in all the vowel contexts

for SJY.

Conclusion: All the three vowels /a, i, u/ ***facilitated*** the production of ***nasal retroflex*** in ***SJY***.

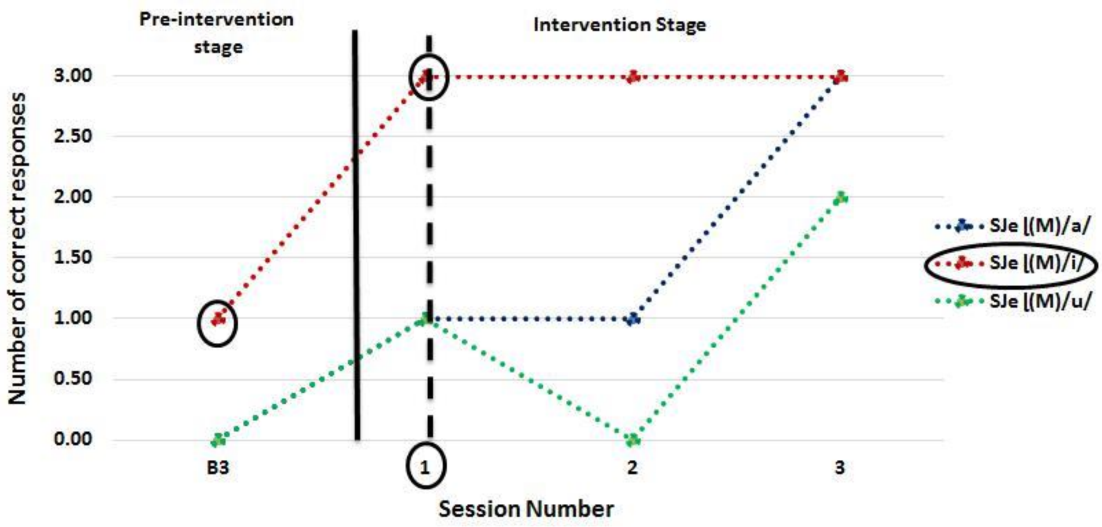
Vowel /u/ highly facilitated the production of nasal retroflex /ɳ/ in all the participants. This can be possibly due to the physiological basis in the production of vowel /u/ with lips protruded, the distance between the tongue and the palate is less, and the tongue is moving upward while producing /ɳu/ making it easier to produce nasal retroflex /ɳ/.

In sum, the context ***vowel /u/ with target in the medial position, T(M)/u/ (e.g. /haɳɳu/)*** was the ***highly facilitating*** context for the production of ***nasal retroflex /ɳ/***.

4.6. Facilitating context for lateral retroflex /ɭ/ (3 participants)

Similar to nasal retroflex, facilitating vowels are established for lateral retroflex /ɭ/ as it occurs only in the medial position in Kannada.

1) Participant SJe.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.57. Number of correct responses (NCR) vs. sessions for lateral retroflex /ɭ/

Pre-intervention stage: Lateral retroflex /ɭ/ is emerging in the context of vowel /i/ at B3 (Fig. 4.57).

Intervention stage:

- *Magnitude of behavior*: It is evident from Fig. 4.57, that vowel /i/ (e.g. /bi***ḷi***/) highly facilitating the production of /ḷ/.

- *Latency of change in behavior*: At 1st session itself a greater change in correct production of /ḷ/ was observed in context of vowel /i/ (Fig. 4.57).

From Fig. 4.57, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts for /ḷ/ are provided in Table 4.30.

Table 4.30

Minimum number of sessions for acquiring the target phoneme /ḷ/ in different phonetic context for SJe

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SJe	-	-	-	5	1	5

The least session number (LSN) in Table 4.30 is 1. The NCR scores for /ḷ/ in different contexts at session 1 is depicted in Fig. 4.58.

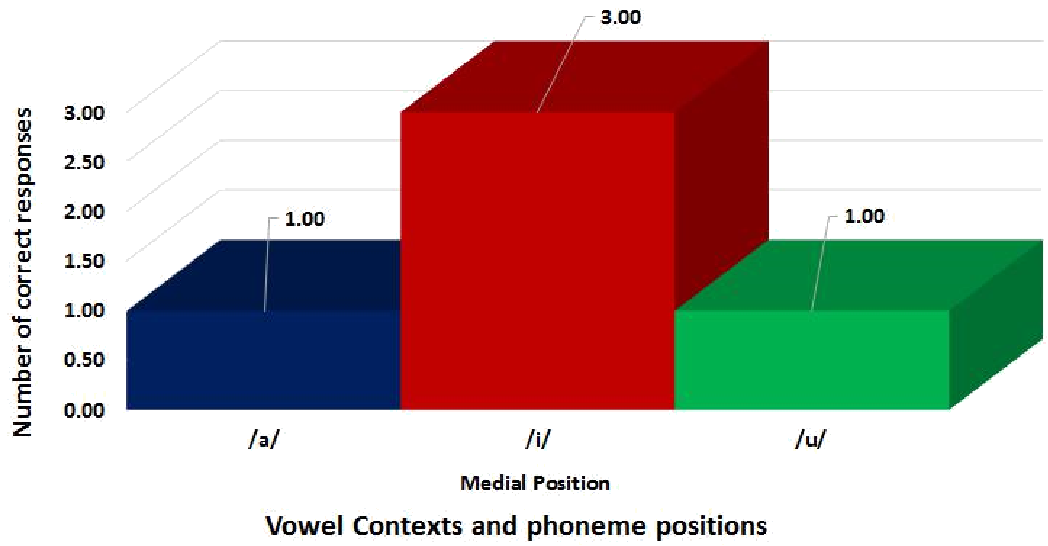
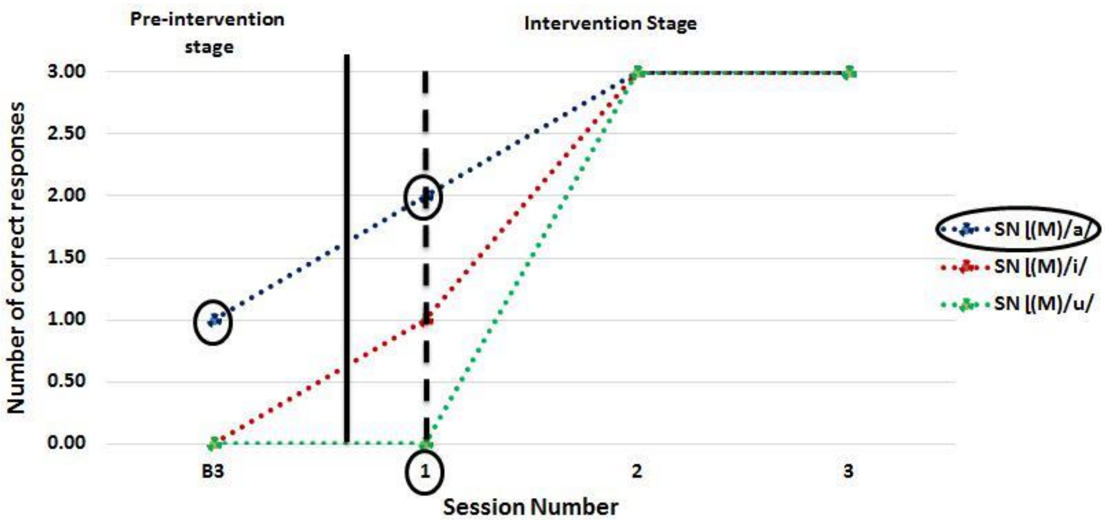


Figure 4.58. Number of correct responses (NCR) in each context at LSN-1 for SJe

From Fig. 4.58 it is evident NCR score is maximum in context of vowel /i/ for SJe.

Conclusion: ***Vowel /i/*** highly ***facilitated*** the production of ***lateral retroflex*** in ***SJe***.

2) Participant SN.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.59.*Number of correct responses (NCR) vs. sessions for lateral retroflex /ɭ/

Pre-intervention stage: Lateral retroflex /ɭ/ is emerging in the context of vowel /a/ at B3 (Fig. 4.59).

Intervention stage:

- *Magnitude of behavior*: It is evident from Fig. 4.59, that vowel /a/ (e.g. /ka***ɭɭa***/) followed by vowel /i/ (e.g. /bi***ɭi***/) is highly facilitating the production of /ɭ/.

- *Latency of change in behavior*: At 1st session itself a greater change in correct production of /ɭ/ was observed in context of vowel /a/ (Fig. 4.59).

From Fig. 4.59, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts for /ɭ/ is provided in Table 4.31.

Table 4.31

Minimum number of sessions for acquiring the target phoneme /ɭ/ in different phonetic context for SN

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SN	-	-	-	1	2	2

The least session number (LSN) in Table 4.31 is 1. The NCR scores for /ɭ/ in different contexts at session 1 is depicted in Fig. 4.60.

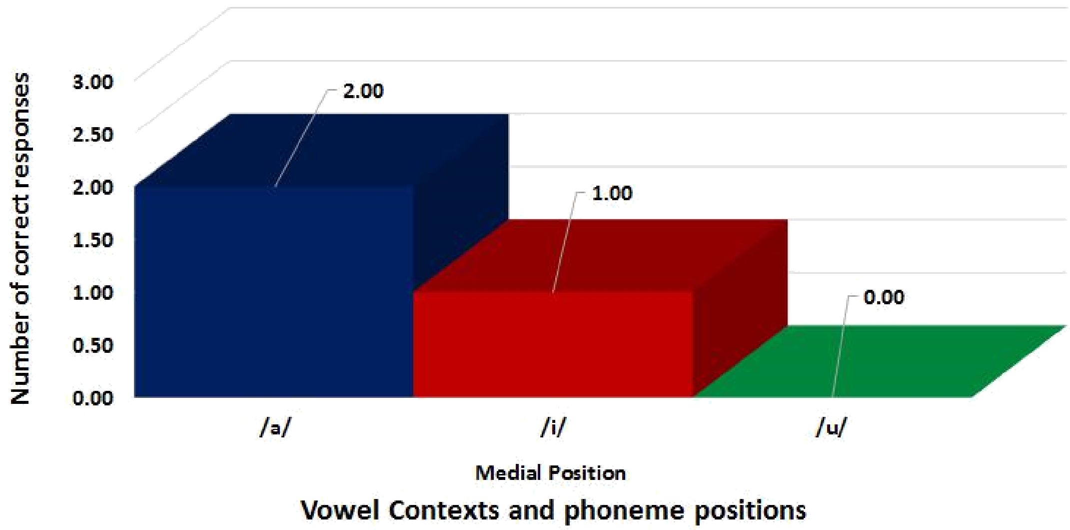
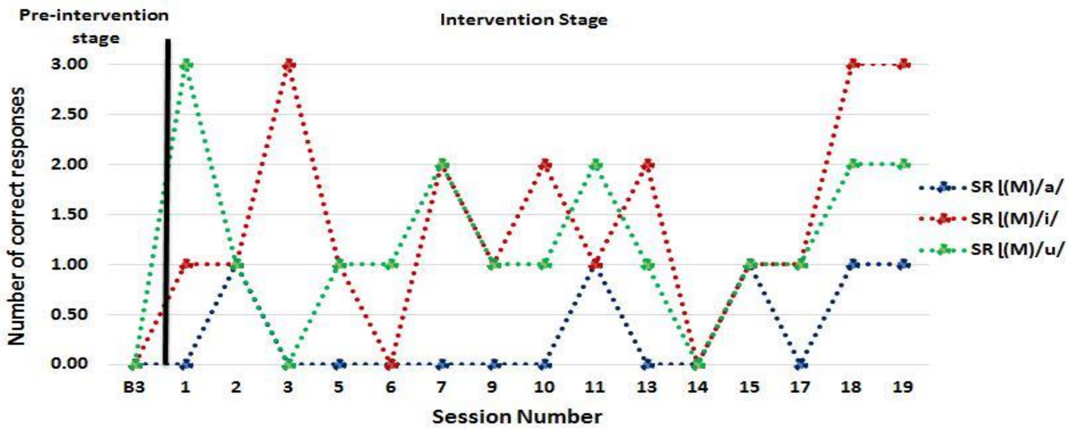


Figure 4.60. Number of correct responses (NCR) in each context at LSN-1 for SN

From Fig. 4.60 it is evident NCR score is maximum in context of vowel /a/ for SN.

*Conclusion: V**owel /a/ (e.g. /*ha*ɭɭa/)*** followed by ***vowel /i/ (e.g. /*ba*ɭɭi/)*** and then ***vowel /u/ with target in the medial position, T(M)/u/ (e.g. /*mu*ɭɭu/) facilitated*** the production of ***lateral retroflex*** in ***SN***.

3) Participant SR.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.61.*Number of correct responses (NCR) vs. sessions for lateral retroflex /ɭ/

Pre-intervention stage: No production of lateral retroflex /ɭ/ at B3 (Fig. 4.61).

Intervention stage:

- *Magnitude of behavior*: It is unpredictable to conclude on magnitude of the behavior due to high variability in production.

- *Latency of change in behavior*: Unpredictable due to high variability in performance (Fig. 4.61).

The minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts could not be established due to high variability.

Conclusion: Facilitating context ***could not be established*** for the production of ***lateral retroflex*** in ***SR***.

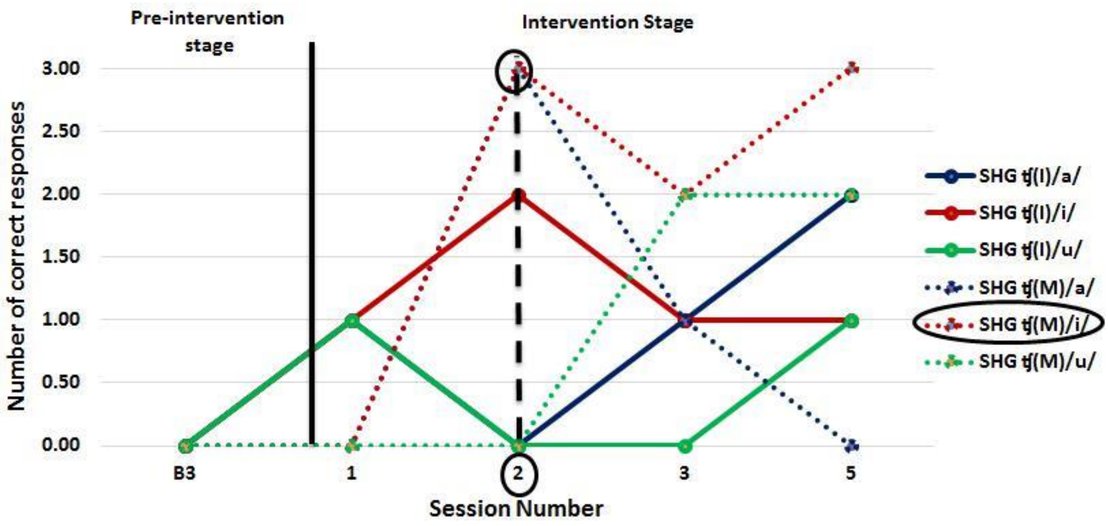
In sum, each of the three participants had different contexts facilitating the production of lateral retroflex /ɭ/; the context T(M)/i/ (e.g. /ba***ɭɭi***/) facilitated in SJe; T(M)/a/ (e.g. /ha***ɭɭa***/) ≈ T(M)/i/ (e.g. /ba***ɭɭi***/) ≈ T(M)/u/ (e.g. /mu***ɭɭu***/) in SN. Facilitating context could not be established for SR due to high variability in performance. A conclusive facilitating context could not be documented for lateral retroflex. This may be probably due to small sample size. Also frequency of occurrence of /ɭ/ is relatively minimal in Kannada (Sreedevi, et al., 2015).

To summarize on results for retroflex, both initial and medial positions facilitated the production of retroflex sounds. This result is in agreement with Shishira and Sreedevi (2013) and Sushma and Sreedevi (2013) who report that both initial and medial positions of a word facilitate the production of Kannada retroflex in typically developing children. These differences are attributed to the anatomical and neural maturation during the course of speech development (Byun, 2012). The motor-control over the differential movements of various parts of the tongue are not acquired completely in typically developing children and hence, have ballistic movements (Kent, 1982; MacNeilage & Davis, 1999). Also, retroflex involves an upward movement of the tongue tip and constriction of the tongue blade at the palate for a narrow stretch with the requirement of more neural commands in Kannada (Kochetov, Sreedevi, Kasim, & Manjula, 2012). Also sounds in the initial position receive the first neural commands without infleunce of other sounds and sounds in the medial position require minimal articulatory adjustments with the adjacent sounds. The salient observation of the study is that even in a small sample of children with SSD, the positional effect was evident.

The results revealed vowel /u/ in the following context to be facilitating the production of sounds /ʈ/, and /ɳ/; vowel /u/ and /a/ for /ɖ/ whereas, /i/ and /a/ facilitating lateral retroflex /ɭ/. These results can be related to the physiological basis underlying the production of target phonemes and the vowels considered. In case of retroflex sounds /ʈ/, /ɖ/, and /ɳ/, the tongue tip is elevated and the constriction of the tongue blade at the palate is for a narrow stretch (Kochetov, Sreedevi, Kasim, & Manjula, 2012). In support of this, Irfana (2017) has also reported retroflex sounds in Kannada to be highly coarticulating in the context of following vowel /u/ compared to other vowels using ultrasound imaging. On the other hand, the lateral-retroflex /ɭ/ is produced as sub-apical palatal with a concave tongue shape with a back curl of the tongue tip and constriction with the underside of the tongue and the hard-palate over a larger area (Narayanan, Byrd, & Kaun, 1999). Proctor, Shadle, and Iskarous, (2010) reported retroflex sounds to be more susceptible to vowel coarticulation as the back cavity volume is more compared to lateral retroflex.

4.7. Facilitating context of voiceless affricate /ʧ/ (2 participants)

1) Participant SHG.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.62. Number of correct responses (NCR) vs. sessions for unvoiced affricate /ʧ/ *Pre-intervention stage:* No production of unvoiced affricate /ʧ/ at B3 (Fig. 4.62).

Intervention stage:

- *Magnitude of behavior*: The highest score (2/3 or 3/3) is in the context T(M)/i/ (e.g. /pa***ʧʧi***/) (Fig. 4.62).

- *Latency of change in behavior*: At 2nd session a significant change in the correct production of /ʧ/ was observed in the context of T(M)/i/ (Fig. 4.62).

From Fig. 4.62, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.32.

Table 4.32

Minimum number of sessions for acquiring the target phoneme /ʧ/ in different phonetic context for SHG

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SHG	>5	>5	>5	>5	2	3

The least session number (LSN) in Table 4.32 is 2. The NCR scores for /ʧ/ in different contexts at session 2 is depicted in Fig. 4.63.

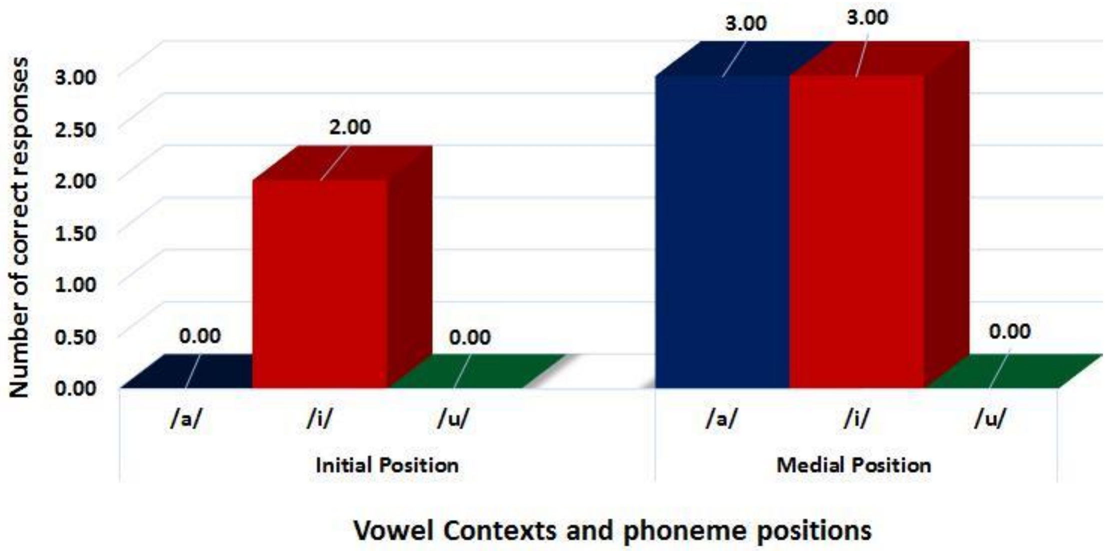
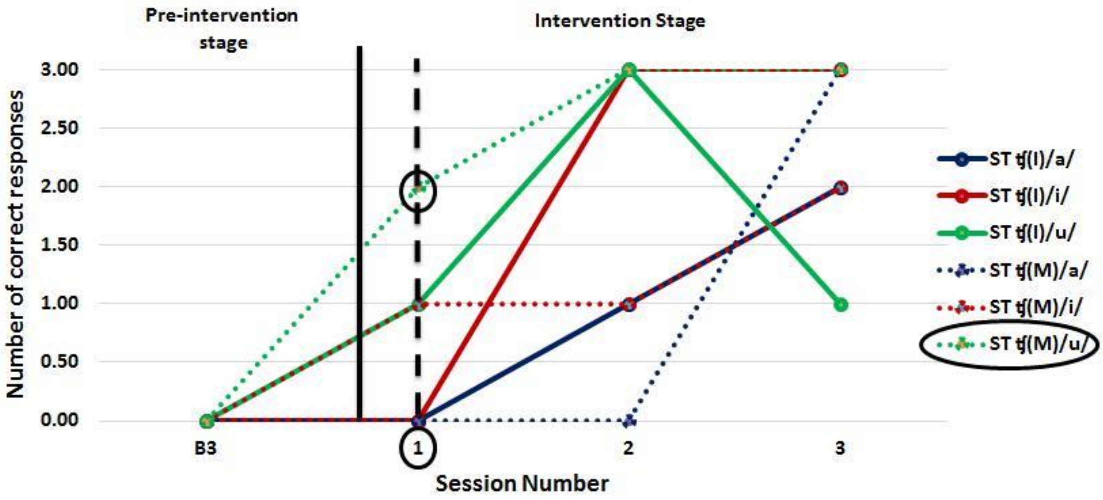


Figure 4.63. Number of correct responses (NCR) in each context at LSN-2 for SHG

From Fig. 4.63 it is evident NCR score is maximum when /ʧ/ is in the medial position followed by vowel /i/ and /a/. However, there is a reduction of scores in the vowel context /a/ after LSN 2.

Conclusion: The phoneme ***/ʧ/*** was highly ***facilitated*** when occurred in the ***medial position followed by vowel /i/ (e.g. /paʧʧi/)*** for ***SHG***.

2) Participant ST.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.64.*Number of correct responses (NCR) vs. sessions for unvoiced affricate /ʧ/

Pre-intervention stage: No production of unvoiced affricate /ʧ/ at B3 (Fig. 4.64).

Intervention stage:

- *Magnitude of behavior*: The highest score (2/3 or 3/3) is in the context T(M)/u/ (e.g. /ka***ʧʧu***/) (Fig. 4.64).

- *Latency of change in behavior*: At 1st session a significant change in the correct production of /ʧ/ was observed in the context of T(M)/u/ (Fig. 4.64).

From Fig. 4.64, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts is provided in Table 4.33.

Table 4.33

Minimum number of sessions for acquiring the target phoneme /ʧ/ in different phonetic context for ST

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
ST	3	2	2	3	3	1

The least session number (LSN) in Table 4.33 is 1. The NCR scores for /ʧ/ in different contexts at session 1 is depicted in Fig. 4.65.

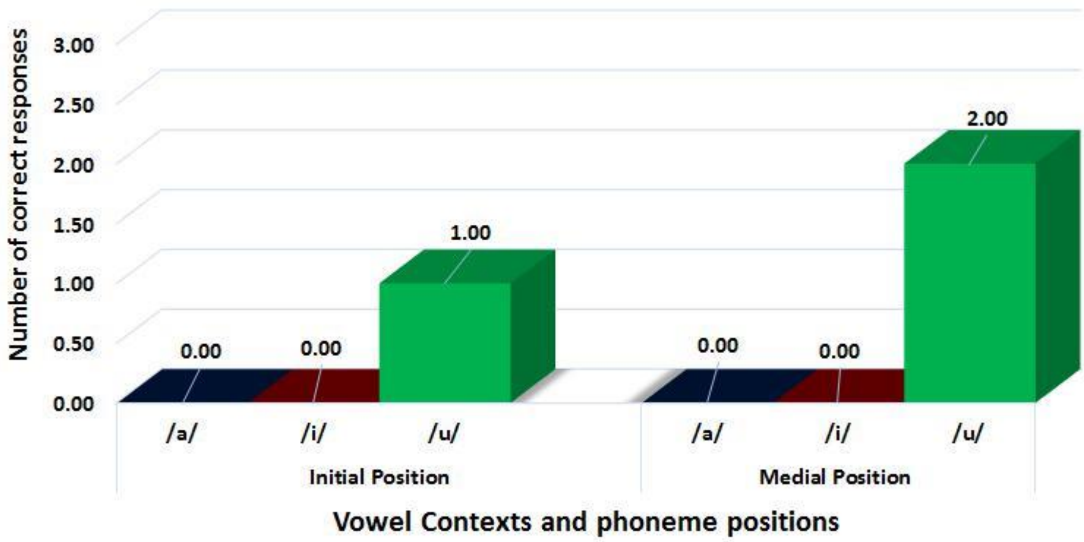


Figure 4.65. Number of correct responses (NCR) in each context at LSN-1 for ST

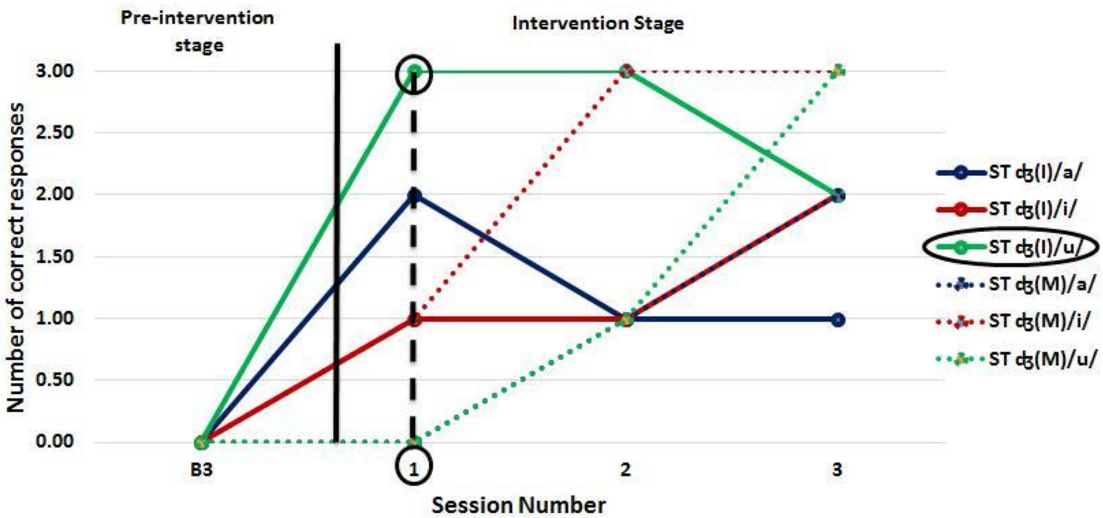
From Fig. 4.65 it is evident NCR score is maximum when /ʧ/ is in the medial position followed by vowel /u/.

Conclusion: Unvoiced affricate ***/ʧ/*** was ***facilitated*** when occurred in the ***medial position followed by vowel /u/*** (e.g. /ka***ʧʧu***/) in ***ST***.

There was a difference in the facilitating context for the two participants; vowel /i/ with target in the medial position facilitated the production of /ʧ/ in SHG attributable to the involvement of similar place of articulation (tongue blade) for the target sound and the vowel (Swisher, 1973) and minimal articulatory constraint from the adjacent sounds at the medial position and is in consonance with Bauman-Waengler (2012); also, in consonance with Merin's (2017) report stating that affricates are facilitated in medial position in Malayalam. Vowel /u/ facilitated the production of /ʧ/ in ST attributable to the poor perception of affricates in high front vowel context (Kalaiah & Bhat, 2017). These differences may be due to the higher severity (moderately severe), fair-inter-discrimination ability, and unintelligible speech in ST compared to SHG.

4.8. Facilitating context of voiced affricate /ʤ/ (3 participants)

1) Participant ST.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

Figure 4.66. Number of correct responses (NCR) vs. sessions for voiced affricate /ʤ/

Pre-intervention stage: No production of voiced affricate /ʤ/ at B3 (Fig. 4.66).

Intervention stage:

- *Magnitude of behavior*: The highest score (2/3 or 3/3) is in the context T(I)/u/ (e.g. /***ʤu***bba/) (Fig. 4.66).

- *Latency of change in behavior*: At 1st session a significant change in the correct production of /ʤ/ was observed in the context of T(I)/u/ (Fig. 4.66).

From Fig. 4.66, the minimum number of sessions required to attain 2/3 or 3/3 scores in three consecutive sessions for different vowel and position contexts for */ʤ/* is provided in Table 4.34.

Table 4.34

Minimum number of sessions for acquiring the target phoneme /ʤ/ in different phonetic context for ST

Participant	**T(I)/a/**	**T(I)/i/**	**T(I)/u/I**	**T(M)/a/**	**T(M)/i/**	**T(M)/u/**
ST	1	3	1	3	2	3

The least session number (LSN) in Table 4.34 is 1. The NCR scores for /ʤ/ in different contexts at session 1 is depicted in Fig. 4.67.

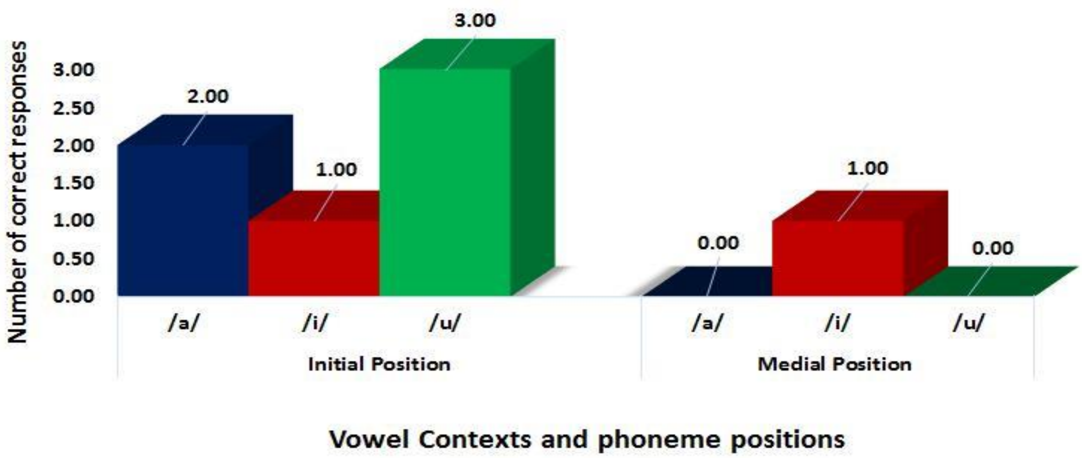
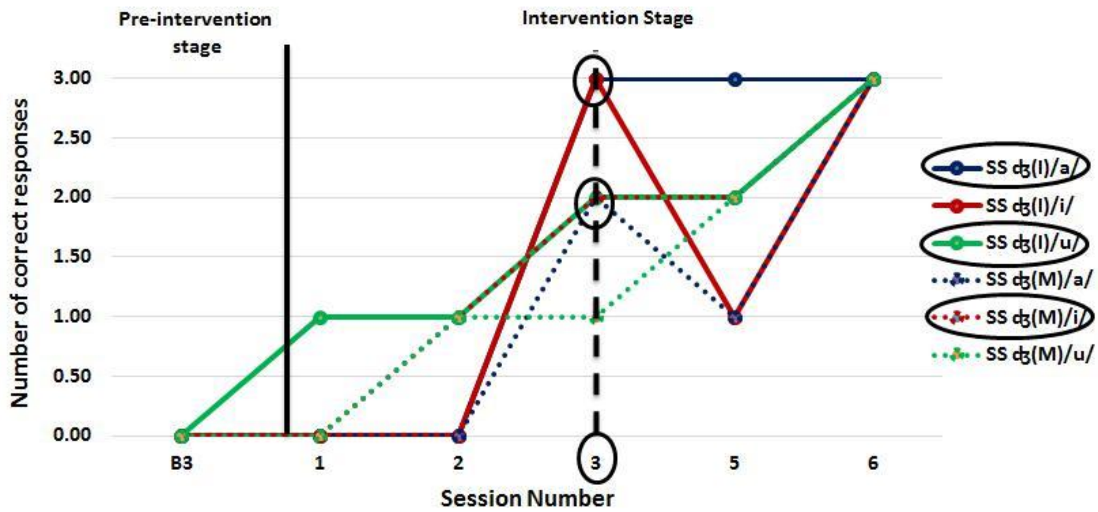


Figure 4.67. Number of correct responses (NCR) in each context at LSN-1 for ST

From Fig. 4.66 it is evident NCR score is maximum when /ʤ/ is in the initial position followed by vowel /u/.

Conclusion: The correct production of voiced affricate ***/ʤ/*** was facilitated when it occurred in the ***initial position followed by vowel /u/, T(I)/u/ (e.g. /ʤu*bba/)**for **ST.***

2) Participant SS.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ○; most facilitating context/s - ⬭ }

Figure 4.68. Number of correct responses (NCR) vs. sessions for voiced affricate /ʤ/

Pre-intervention stage: There was no production of voiced affricate /ʤ/ at B3 (Fig. 4.68).

Intervention stage:

- *Magnitude of behavior*: The NCR score was high in the context of T(I)/a/ (e.g. /***ʤa***na/) followed by T(I)/u/ (e.g. /***ʤu***bba/) and T(M)/i/ (e.g. /a***ʤʤi***/) (Fig. 4.68).

- *Latency of change in behavior*: At 3rd session a significant change in the correct production of /ʤ/ was observed in the context of T(I)/a/, T(I)/u/, and T(M)/i/ (Fig. 4.68).

From Fig. 4.68, the minimum number of sessions required to attain 2/3 or 3/3 scores for /ʤ/ in three consecutive sessions for different vowel and position contexts is provided in Table 4.35.

Table 4.35

Minimum number of sessions for acquiring the target phoneme /ʤ/ in different phonetic context for SS

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SS	3	3	3	3	3	4

The least session number (LSN) in Table 4.35 is 3. The NCR scores for /ʤ/ in different contexts at session 3 is depicted in Fig. 4.69.

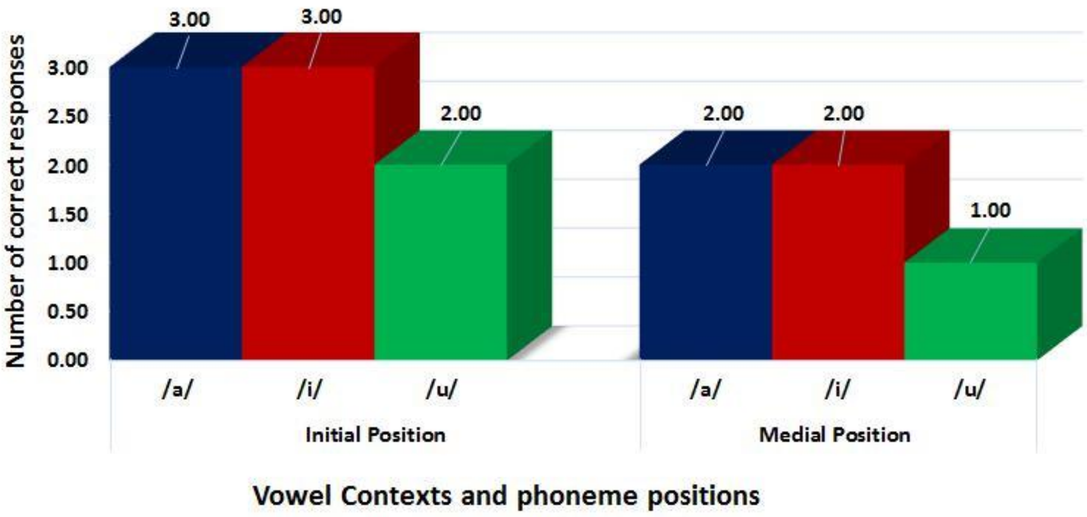
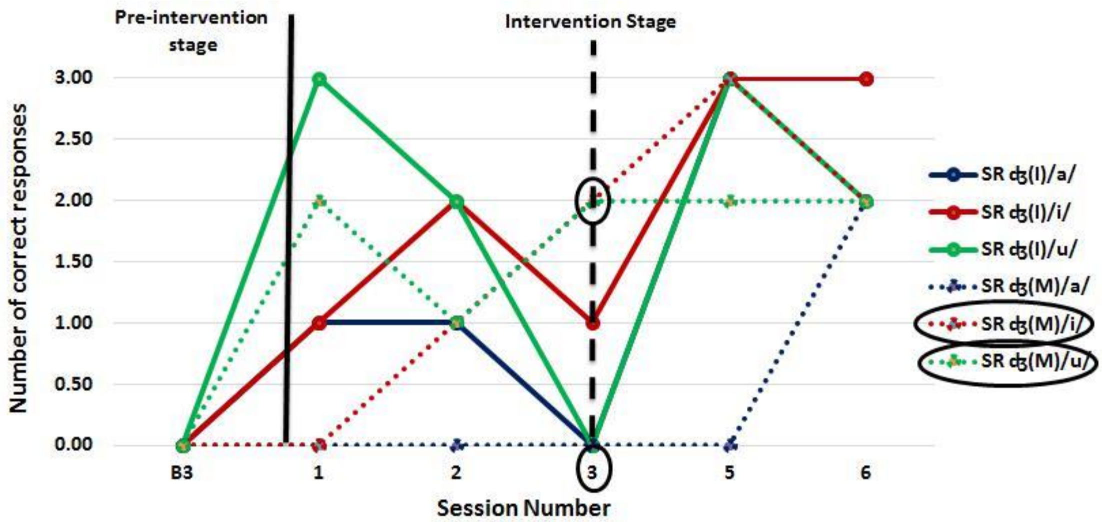


Figure 4.69. Number of correct responses (NCR) in each context at LSN-3 for SS

From Fig. 4.69 it is evident NCR score is high in all the contexts except /ʤ/ in the medial position followed by vowel /u/. However, a score of 2/3 or 3/3 in three consecutive sessions was retained only in the contexts of T(I)/a/, T(I)/u/, and T(M)/i/.

Conclusion: Voiced affricate ***/ʤ/*** was ***facilitated*** when it was in the ***initial position followed by either vowel /a/ or /u/*** and in the ***medial position followed by vowel /i/*** for SS.

3) Participant SR.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.70.*Number of correct responses (NCR) vs. sessions for voiced affricate /ʤ/

Pre-intervention stage: There is consistent error production of voiced affricate /ʤ/ at B3 (Fig. 4.70).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was more in the contexts of T(M)/i/ (e.g. /a***ʤʤi***/) and T(M)/u/ (e.g. /uʤʤu/) (Fig. 4.70).

- *Latency of change in behavior*: At 3rd session a noted change in the correct production of /ʤ/ was observed in the context of T(M)/i/ andT(M)/u/ (Fig. 4.70).

From Fig. 4.70, the minimum number of sessions required to attain 2/3 or 3/3 scores for the production of /ʤ/ in three consecutive sessions for different vowel and position contexts is provided in Table 4.36.

Table 4.36

Minimum number of sessions for acquiring the target phoneme /ʤ/ in different phonetic context for SR

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SR	4	4	5	5	3	3

The least session number (LSN) in Table 4.36 is 3. The NCR scores for /ʤ/ in different contexts at session 3 is depicted in Fig. 4.71.

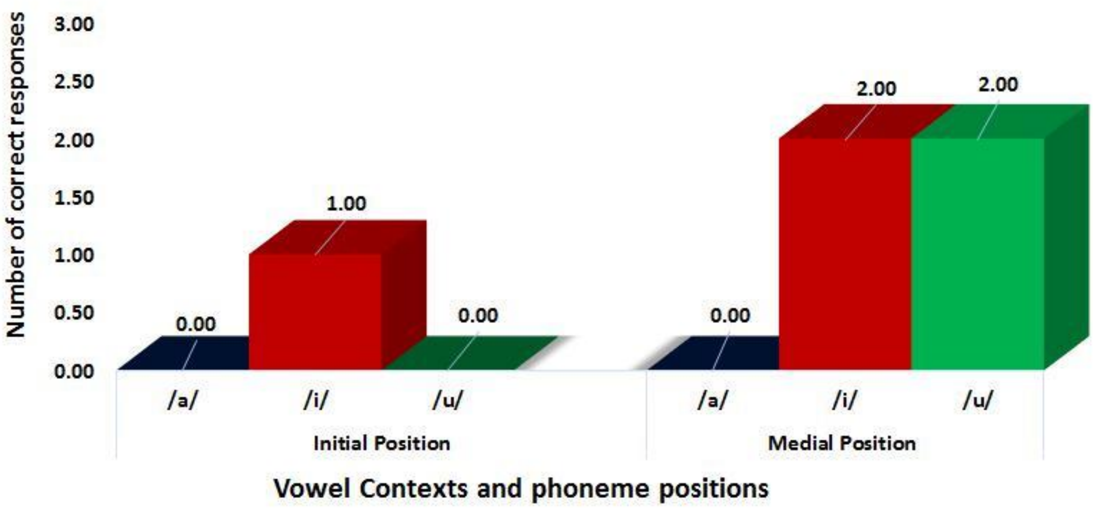


Figure 4.71. Number of correct responses (NCR) in each context at LSN-3 for SR

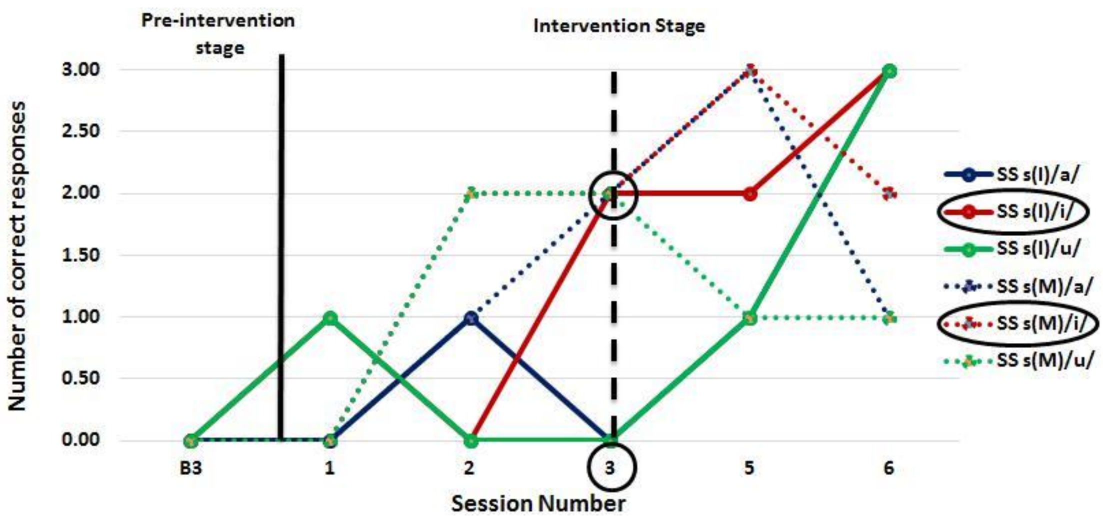
From Fig. 4.71 it is apparent that more number of correct responses of /ʤ/ are present in the contexts of T(M)/i/ and T(M)/u/ for SR

Conclusion: The correct production of the voiced affricate ***/ʤ/*** was highly ***facilitated*** when it was in the ***medial position followed by either vowel /i/ or /u/*** in ***SR***.

Cumulative findings from three participants revealed varied contexts facilitating the production of voiced affricate /ʤ/. Context T(I)/u/ facilitated the production of /ʤ/ in ST; T(I)/u/, T(I)/a/, and T(M)/i/ in SS; and T(M)/i/ and T(M)/u/ in SR. From these findings it can be inferred that irrespective of target phoneme /ʤ/ position, vowels /i/ and /u/ are more facilitating than vowel /a/. The findings are in consonance with reports in English where affricate perception is better in the context of /i/.Swisher's (1973) physiological analogy also holds good here supporting the fact that the articulatory gestures are similar for /i/ and /ʤ/ leading to facilitatory effect. Vowel /u/ is also found to be facilitating which can be attributed to reduced distance between palate and tongue making it easier for upward movement of the tongue. The finding that vowel /a/ is less facilitating is not in consonance with Kalaiah and Bhat (2017) that affricates in Kannada are poorly recognized in the high vowel contexts and recognized better in low vowels. This may be probably because Kalaiah and Bhat had considered adults as participants and in the present study school-going children serve as participants and the perception of sounds differ across children and adults (Nitrrouer & Kennedy, 1987). The results on phoneme position for affricates are in agreement with Bleile's (1996) observations reporting voiceless consonants are facilitated in the end position of the word and voiced consonants in the beginning of the word.

4.9. Facilitating context of fricative /s/ (3 participants)

1) **Participant SS.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.72.*Number of correct responses (NCR) vs. sessions for unvoiced fricative /s/

Pre-intervention stage: There is no production of unvoiced affricate /s/ at B3 (Fig. 4.72).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was more in the context of T(M)/i/ (e.g. /ma***si***/) followed by T(I)/i/ (e.g. /***si***mha/) (Fig. 4.72).

- *Latency of change in behavior*: At 3rd session a clear change in the correct production of /s/ was observed in the context of T(M)/i/ and T(I)/i/ (Fig. 4.72).

From Fig. 4.72, the minimum number of sessions required to attain 2/3 or 3/3 scores for the production of /s/ in three consecutive sessions for different vowel and position contexts is provided in Table 4.37.

Table 4.37

Minimum number of sessions for acquiring the target phoneme /s/ in different phonetic context for SS

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SS	>3	3	>3	>3	3	>3

The least session number (LSN) in Table 4.37 is 3. The NCR scores for /s/ in different contexts at session 3 is depicted in Fig. 4.73.

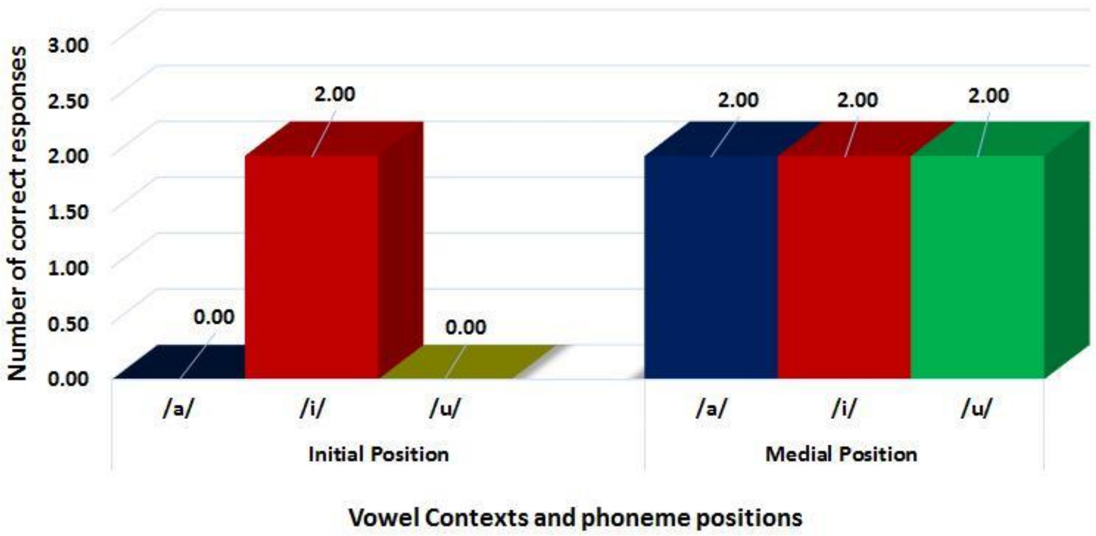
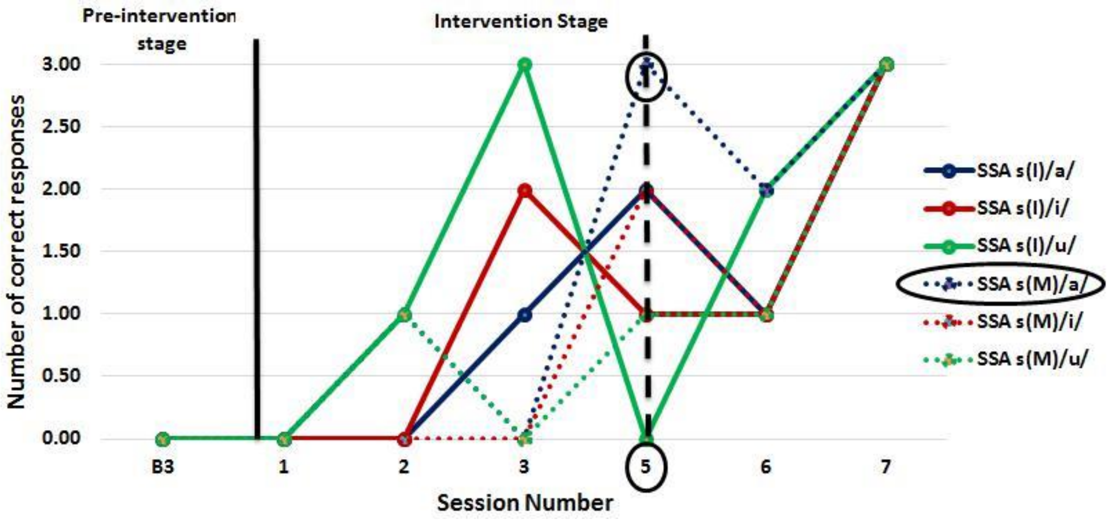


Figure 4.73. Number of correct responses (NCR) in each context at LSN-3 for SS

From Fig. 4.73 it is apparent that more number of correct responses of /s/ are present in the contexts of T(M)/i/ and T(I)/i/ for SS. It is also observed that 2/3 scores are present in the context of /s/ in the medial position followed by vowel /a/ and /u/, but, the productions are not stabilized across three consecutive sessions.

Conclusion: Unvoiced fricative ***/s/*** was ***facilitated*** when it occurred in ***either initial or medial position followed by vowel /i/*** for ***SS***.

2) **Participant SSA.**



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.74.*Number of correct responses (NCR) vs. sessions for unvoiced fricative /s/

Pre-intervention stage: No correct production of unvoiced affricate /s/ at B3 (Fig. 4.74).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was more in the context T(M)/a/ (e.g. /ka***sa***/) (Fig. 4.74).
- *Latency of change in behavior*: At 4th intervention session a significant change in the correct production of /s/ was observed in the context of T(M)/a/ (Fig. 4.74).

From Fig. 4.74, the minimum number of sessions required to attain 2/3 or 3/3 scores for the production of /s/ in three consecutive sessions for different vowel and position contexts is provided in Table 4.38.

Table 4.38

Minimum number of sessions for acquiring the target phoneme /s/ in different phonetic context for SSA

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
SSA	6	6	5	4	4	6

The least session number (LSN) in Table 4.38 is 4. The NCR scores for /s/ in different contexts at session 4 is depicted in Fig. 4.75.

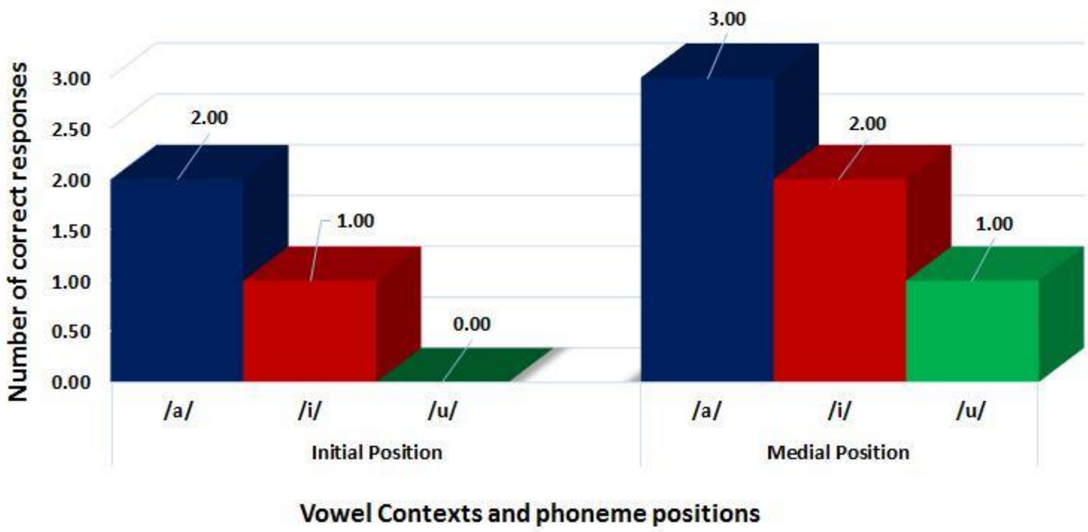
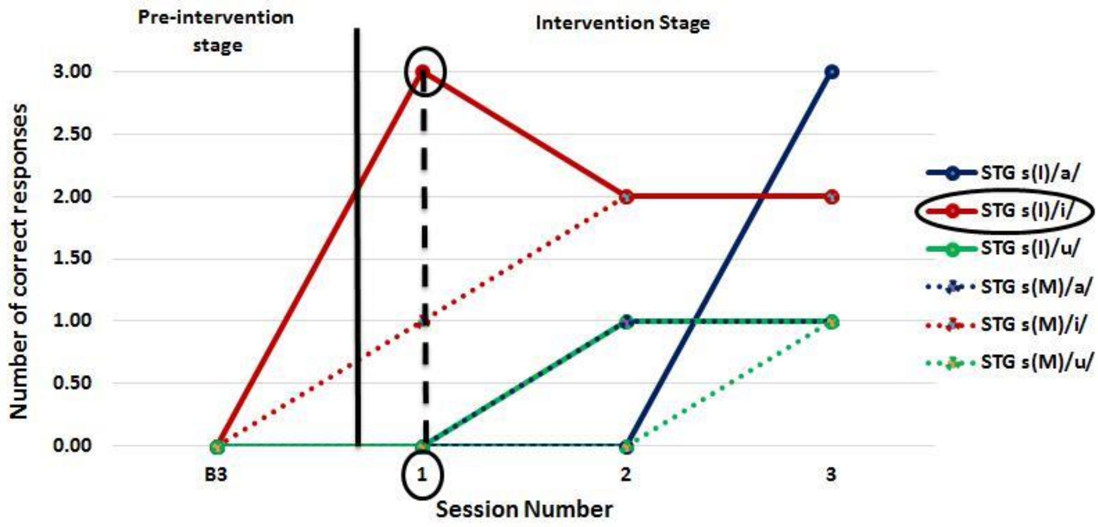


Figure 4.75. Number of correct responses (NCR) in each context at LSN-4 for SSA

From Fig. 4.75 it is evident that more number of correct responses of /s/ are present in the contexts of T(M)/a/ for SSA. It is also observed that 2/3 scores are present in the context of /s/ in the initial position followed by vowel /a/ and medial position followed by vowel /i/, but, the productions are not stabilized across three consecutive sessions.

Conclusion: Fricative ***/s/*** was ***facilitated*** in the ***medial position followed by vowel /a/*** for ***SSA***.

3) Participant STG.



{Solid line – initial position; dotted line – medial position; blue line – vowel /a/; red line – vowel /i/; and green line – vowel /u/; Least Session Number (LSN) - ◯; most facilitating context/s - ⬭ }

*Figure 4.76.*Number of correct responses (NCR) vs. sessions for unvoiced fricative /s/

Pre-intervention stage: No correct production of unvoiced fricative /s/ at B3 (Fig. 4.76).

Intervention stage:

- *Magnitude of behavior*: The number of correct responses was more in the context T(I)/i/ (e.g. /***si***ʈʈu//) (Fig. 4.76).

- *Latency of change in behavior*: At 1st session itself a significant change in the correct production of /s/ was observed in the context of T(I)/i/ (Fig. 4.76).

From Fig. 4.76, the minimum number of sessions required to attain 2/3 or 3/3 scores for the production of /s/ in three consecutive sessions for different vowel and position contexts is provided in Table 4.39.

Table 4.39

Minimum number of sessions for acquiring the target phoneme /s/ in different phonetic context for STG

Participant	T(I)/a/	T(I)/i/	T(I)/u/I	T(M)/a/	T(M)/i/	T(M)/u/
STG	3	1	4	2	4	2

The least session number (LSN) in Table 4.39 is 1. The NCR scores for /s/ in different contexts at session 1 is depicted in Fig. 4.77.

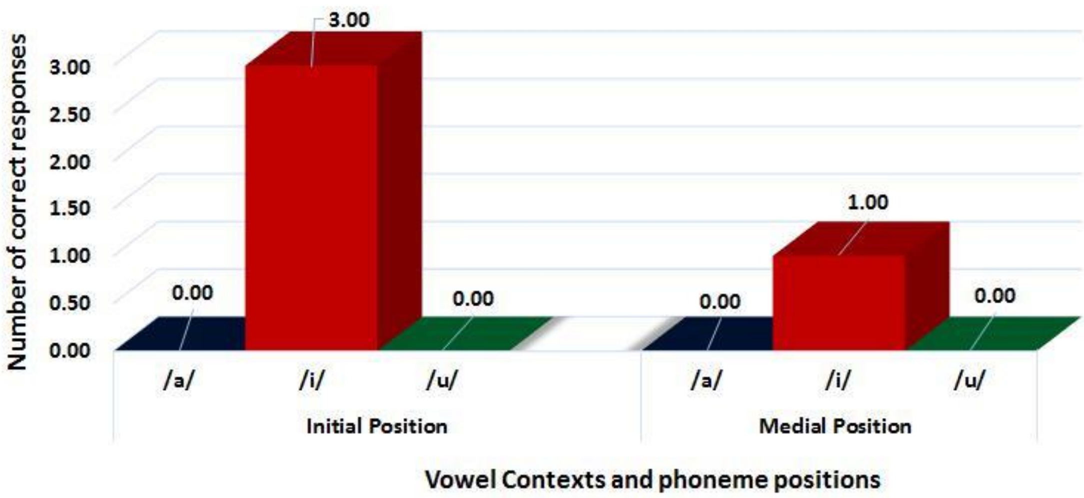


Figure 4.77. Number of correct responses (NCR) in each context at LSN-1 for STG

It is apparent from Fig 4.77, that maximum correct responses of /s/ was in the contexts of T(I)/i/ for STG.

Conclusion: ***Fricative /s/*** production was facilitated when it occurred in the ***initial position followed by vowel /i/*** for ***STG***.

The intervention data showed consistent facilitatory effect of vowel /i/ for participants SS and STG irrespective of its position in the word. These results are in consonance with many earlier studies (Elbert & McReynolds, 1978; Zehel et al., 1972; Mowrer, 1989) stating that vowel /i/ is facilitating the production of fricative /s/ and correctness of sound /s/ is not affected by phoneme position with respect to lexical boundaries or phonological acceptability of sequences (Gallagher & Shriner, 1975b).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. Perceptual studies also support the fact that medial consonants are accurately identified in the context of vowel /i/ and the present findings are in consonance with it. The present findings are not in consonance with the perceptual study by Kalaiah and Bhat (2017) stating that vowels have least influence on fricative production. This discrepancy may be due to the population considered for the two studies. 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 (Nitrrouer & Kennedy, 1987). Vowel /a/ facilitated the production of /s/ in SSA which can be due to high coarticulatory nature of vowel /a/ (Swisher, 1973).

Medial position is facilitating the production of /s/ in SS and SSA and is in consonance with the findings of Kent (1982) and Bleile (1996) indicating that fricative /s/ is acquired in the medial or final position. On the other hand, initial position is facilitating the production of /s/ in STG and this result is in consonance with the findings of Gallagher and Shriner (1975b) indicating that fricative /s/ is acquired in the initial position.

Cumulating all the findings, it is notable that for 85% of the participants in the present study facilitating vowel contexts and phoneme positions could be established indicating the definite effect of phonetic contexts on the production of various speech sounds. However, one participant exhibited variations in performance and consequently the facilitating context could not be established for lateral retroflex /ɭ/. The merit of the study was that, all the participants received intervention until they acquired the target phoneme completely in all the phonetic contexts and post-intervention evaluations revealed maintenance of the learnt phonemes in 14 of the 15 participants. Also, continuous assessment results ensured the presence of internal validity with correct production of phonemes in untrained words for all the participants.

Another salient observation was that the facilitating phonetic contexts were observed to vary depending on the severity of the articulatory problem, intelligibility level, discrimination ability and type of errors. The details on facilitating vowel contexts and phoneme positions are provided in Table 4.40.

In addition, the present study on pattern of vowel and phoneme position effect was similar to previous reports in Malayalam (Anu rose, 2017; Merin, 2017), and English (Bleile, 1996 & 2006; Bauman-Waengler, 2012). On the other hand, the transfer of feature information was different across languages based on the cues provided by consonants in each language. This resulted in the differences in the facilitating phonetic contexts for certain speech sound combinations.

Table 4.40

Facilitating vowel contexts and phoneme positions for specific speech sounds

Characteristics	Speech Sounds	Facilitating vowel	Facilitating position	Facilitating Context
• **Severity:** Mild – mildly moderate • **Intelligibility:** Mostly intelligible in conversation • **Inter-discrimination ability:** Good • **Error type**: Consistent substitution errors with no omission of consonants in any position of the word	1. Voiceless Velar /k/	/a/	Initial	/k/ in the initial position followed by vowel /a/, **k(I)/a/** (e.g. /***ka***pi/, /***ka***bbu/, etc.)
	2. Voiced Velar /g/	High variability across participants		
	3. Voiceless Retroflex /ʈ/	/u/	Initial and medial	Vowel /u/ with **/ʈ/** in the initial position, **T(I)/u/** or in the medial position, **ʈ(M)/u/** (e.g. /***ʈu:***ru/, /gu***ʈʈu***/, etc)
	4. Voiced Retroflex /ɖ/	/u/ and /a/	Initial and medial	/ɖ/ in the initial position followed by vowel /u/ or /a/, **ɖ(I)/u/** or **ɖ(I)/a/** , **ɖ (M)/a/(**e.g. /***ɖu***mmu/, /***ɖu***bba/, /***ɖa***bbi/, /ga***ɖɖa***/ etc)
	5. Nasal Retroflex /ɳ/	/u/	Medial	/ɳ/ in the medial position followed by vowel /u/, **ɳ(M)/u/** (e.g. /ha***ɳɳu***/, /ma***ɳɳu***/, /ka***ɳɳu***/, etc)
	6. Lateral Retroflex /ɭ/	/i/ and /a/	Medial	Following lax vowels /i/or /a/, **ɭ(M)/i/** or **ɭ(M)/a/,** (e.g. /ha***ɭɭi***, /hu***ɭi***/, /ka***ɭɭa***/, /hava***ɭa***/, etc)

Table 4.40. Continued….	7. Voiceless Affricate /ʧ/	/i/	Medial	/ʧ/ in medial position followed by vowel /i/, **ʧ(M)/i/** (e.g. /mu***ʧʧi***/, /ka***ʧʧi***/, etc)
	8. Voiced Affricate /ʤ/	/i/ and /u/	Initial and medial	/ʤ/ in initial or medial position followed by either vowel /i/ or /u/, **ʤ(I or M)/i, u/** (e.g. /***ʤu***bba/, /***ʤi***nke/**.**, /***aʤʤi***/, /***uʤʤu***/, etc)
	9. Voiceless Fricative /s/	/i/	Initial and medial	Following vowel /i/ with target either in medial or initial position, **T(I)/i/** or **T(M)/i/** (e.g. /***si***:re/, /ma***si***/, etc)
• **Severity:** Moderately severe (velars); Mildly moderate – severe (retroflex and other sounds) • **Intelligibility:** Mostly unintelligible in conversation • **Inter-discrimination ability:** Fair	1. Voiceless Velar /k/	/i/	Medial	/k/ in the medial position followed by vowel /i/, **k(M)/i/** (e.g. /a***kki***/, /ʧi***kki***/ etc)
	2. Voiced Velar /g/	High variability across participants		
	3. Voiceless Retroflex /ʈ/	/u/	Initial and medial	Vowel /u/ with **/ʈ/** in the initial position, **T(I)/u/** or in the medial position, **ʈ(M)/u/** (e.g. /***ʈu:***ru/, /gu***ʈʈu***/, etc)
	4. Voiced Retroflex /ɖ/	/a/	Medial	/ɖ/ in the medial position followed by vowel /a/ **T(M)/a/** (e.g. /gaɖ***ɖa***i/, etc)

Table 4.40. Continued…..

• **Error type:** Consistent or inconsistent errors; substitutions; omissions in initial position or medial position of the word; assimilations	5. Nasal Retroflex /ɳ/	/u/	Medial	/ɳ/ in the medial position followed by vowel /u/, **ɳ(M)/u/** (e.g. /ha***ɳɳu***/, /ma***ɳɳu***/, /ka***ɳɳu***/, etc)
	6. Lateral Retroflex /ɭ/	/i/ and /a/	Medial	Following lax vowels /i/or /a/, **ɭ(M)/i/** or **ɭ(M)/a/,** (e.g. /ha***ɭɭi***, /hu***ɭi***/, /ka***ɭɭa***/, /hava***ɭa***/, etc)
	7. Voiceless Affricate /ʧ/	/u/	Medial	/ʧ/ in the medial position followed by vowel /u/, ***ʧ(M)/u/*** (e.g. /muʧ***ʧ***u/, etc)
	8. Voiced Affricate /ʤ/	/i/ and /u/	Initial and medial	/ʤ/ in initial or medial position followed by either vowel /i/ or /u/, **ʤ(I or M)/i, u/** (e.g. /***ʤu***bba/, /***ʤi***nke/., /***aʤʤi***/, /***uʤʤu***/, etc)
	9. Voiceless Fricative /s/	/i/	Initial and medial	Following vowel /i/ with target either in medial or initial position, **T(I)/i/** or **T(M)/i**/ (e.g. /***si***:re/, /ma***si***/, etc)

4.10. Reliability

The inter- and intra-judge reliability (α) was in the range of acceptable to excellent. Majority of the speech sounds had excellent ($0.9 \leq \alpha$) inter- and intra-judge reliability in most of the contexts followed by good reliability ($0.8 \leq \alpha < 0.9$) in few contexts and acceptable reliability ($0.7 \leq \alpha < 0.8$) in least number of contexts.

4.11. Validation

In Phase 2, two participants, SJA and SD, participated in the validation of Phase-1 findings. These two were not part of Phase I study. Participants SJA and SD had mildly moderate and severe articulatory problems respectively. The validation phase concerned regarding the findings on the effect of vowel and phoneme position context on the production of velar /k/. The effect of the highly facilitating context T(I)/a/ was tested on both participants during validation. The findings of graphical analysis of the data are depicted in Fig. 4.78.

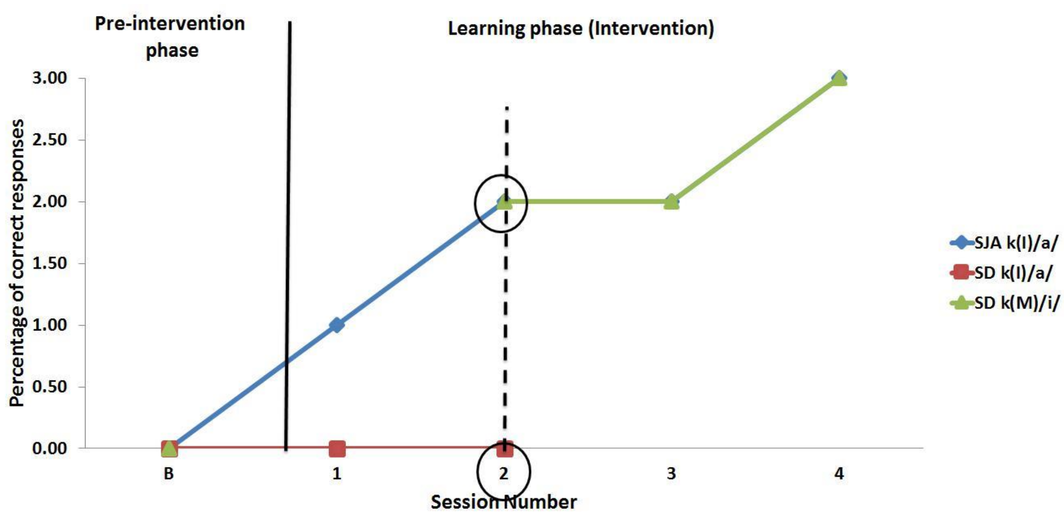


Figure 4.78. The effect of highly facilitating context for the production of voiceless velar /k/ in Phase 2

It can be noted from Fig. 4.78 that there was a significant change in the correct production of /k/ by first session in the context of T(I)/a/ for SJA but not for SD. Even in the second session the scores remained zero for SD in the context of T(I)/a/ and as per the findings of Phase-1 the context T(M)/i/ was introduced as the severity of the problem was very high. A significant change in the correct production of velar /k/ was noticed after introducing the new context T(M)/i/ for SD, validating the following two findings:

1. Vowel contexts and phoneme positions have a definite effect on the correct production of speech sounds.
2. The selection of facilitating phonetic contexts may dependent on the severity of the articulatory problem

Hence, both the hypotheses 1 and 2 of the present study are rejected

1. There will be no contextual effect of vowels /a/, /i/, and /u/ on the production of speech sounds in children with SSD through articulatory intervention.
2. There will be no effect of phoneme positions (initial or medial) on the production of speech sounds in children with SSD through articulatory intervention

Chapter 5: Summary and Conclusions

The present study aimed to investigate the effect of vowel contexts and phoneme positions on the production of speech sounds in Kannada speaking children with speech sound disorder. A total of 15 children with phonetic type SSD underwent intervention for articulatory errors. Among the 15 participants, 6 were enrolled for the correction of /k/, 4 participants for /g/, 5 for /ʈ/, 5 for /ɖ/, 8 for /ɳ/, 3 for /ɭ/, 2 for /ʧ/, 3 for /ʤ/, and 3 for /s/.

The stimuli included bi-and tri-syllabic true words where the target phonemes were either in initial or medial position in one of the three vowel contexts, /a/, /i/, and /u/. For example if target phoneme is velar /k/, the stimuli were /***ka***ppe/, /***ki***vi/, /***ku***ɖi/, /a***kka***/, /a***kki***/, and /bu***kku***/.

The main study involved pre-intervention stage followed by intervention stage and then post-intervention stage. Participants were assessed for articulatory abilities as per ethical considerations at three data points each during pre- (B1, B2, & B3) and post- (P1, P2, & P3) intervention stages to ensure error consistency and maintenance of the learnt production respectively. During intervention stage, participants were asked to repeat the stimuli presented and on incorrect repetition, correct production of the target phoneme was taught using phonetic placement procedures. In a single session, a maximum of five chances were provided to learn the target phoneme in a particular phonetic context, and only the first production of the target word was considered for scoring. The number of correct responses and the minimum number of sessions required to attain 2/3 or 3/3 correct productions in three consecutive sessions served as dependent variables and were documented. The data was represented graphically for each participant to carry out visual analysis and also were subjected to non-parametric statistical analysis. However, 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 these quantitative analysis. In addition, the Wilcoxon Sign Rank test showed significant difference across pre-post intervention for all the phonetic contexts. This is because, baseline score was zero and post-intervention score was 100% for the target phoneme in most of the phonetic contexts. Hence, quantitative 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. Therefore, the results are explained using graphical representations for each participant. The results revealed the following contexts to facilitate the production of target phonemes considered (Table 5.1)

Table 5.1

Facilitating contexts for various speech sounds in Kannada

Target	**Severity of articulatory errors**			
	Mild – mildly moderate	**Example**	**Mildly moderate to severe**	**Example**
Velar /k/	/k/ in the initial position followed by vowel /a/	/***ka***ppe/	/k/ in the medial position followed by vowel /i/	/a***kki***/
/g/	High variability across participants	-	High variability across participants	-
Retroflex /ʈ/	/ʈ/ in either initial or medial position followed by vowel /u/	/***ʈu:***ru/ /gu***ʈʈu***/	/ʈ/ in either initial of medial position followed by vowel /u/	/***ʈu:***ru/ /gu***ʈʈu***/
/ɖ/	/ɖ/ in either initial or medial position followed by either vowel /u/ or /a/	/***ɖu***bba/ /***ɖa***bbi/ / ga***ɖɖa***/ /du***ɖɖu***/	/ɖ/ in the medial position followed by vowel /a/	/ ga***ɖɖa***/

Table 5.1.
Continued...

/ɳ/	/ɳ/ in the medial position followed by vowel /u/	/ha***ɳɳu***/	/ɳ/ in the medial position followed by vowel /u/	/ha***ɳɳu***/
/ɭ/	/ɭ/ in the medial position followed either by vowel /i/ or /a/	/hu***ɭi***/ /ka***ɭɭa***	/ɭ/ in the medial position followed either by vowel /i/ or /a/	/hu***ɭi***/ /ka***ɭɭa***
Affricate /ʧ/	/ʧ/ in the medial position followed by vowel /i/	/mu***ʧʧi/***	/ʧ/ in the medial position followed by vowel /u/	/ka***ʧʧu/***
/ʤ/	/ʤ/ in either initial or medial position followed by either vowel /i/ or /u/	/***ʤu***bba/ /***ʤi***nke/ /a***ʤʤi***/ /u***ʤʤu***/	/ʤ/ in either initial or medial position followed by either vowel /i/ or /u/	/***ʤu***bba/ /***ʤi***nke/ /a***ʤʤi***/ /u***ʤʤu***/
Fricative /s/	/s/ in either initial or medial position followed by vowel /i/	/***si***:re/ /ma***si***/	/s/ in either initial or medial position followed by vowel /i/	/***si***:re/ /ma***si***/

The above results highlight the distinct effect of vowel contexts and phoneme positions on the production of speech sounds in children with SSD. It was observed that the facilitating contexts varied across participants at times. This may be probably due to differences in severity of the articulatory errors, intelligibility level, discrimination ability and type of errors. Also, the present findings are established on phonetic type of SSD. It would be interesting to apply these established contexts on phonemic type of SSD. 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, the articulatory intervention program was continued for all the 15 participants until they achieved the target phonemes and the three post intervention data points ensured the maintenance of the phonemes learnt. Secondly, the internal validity was ensured by conducting continuous assessments during intervention and external validity by applying the present findings of /k/ on other participants with SSD. These aspects increased the rigidity of the case study 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 neighboring 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.

Implications

The results of the present study have notable benefits in the area of intervention of children with speech sound disorders in Kannada. The overall study and its result 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 SSD.

Generally, contextual and positional effects are ignored during articulatory intervention. 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 reduce the duration of articulatory intervention and ensure faster improvement.

Future directions

- To carry out similar studies on large sample size
- To apply the established phonetic contexts in other communication disorders like Phonemic SSD, HI and MR
- To investigate the facilitating context first in the voiced cognate of the phoneme followed by unvoiced cognate
- 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 context

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Appendix 1

Kannada vowel and consonant inventory (Irene Thompson, 2016)

Vowels

The Mysore dialect of Kannada has 15 vowel phonemes, i.e., sounds that make a difference in word meaning, All but one vowel (/ə/) can be short or long. Vowel length makes a difference in word meaning. In addition, there are two diphthongs: /ai/ and /au/.

	Front	**Central**	**Back**
Close	**i, ī**		**u, ū**
Close-mid	**e, ē**		**o, ō**
Mid		**ə**	
Open-mid	**ɛ, ɛ̄**		**ɔ, ɔ̄**
Open		**a, ā**	

- /ɛ/ =*e* in *bed*
- /ə/ = *a* in *about*
- /ɔ/ = *o* in *bog*

Consonants

Mysore Kannada has a large number of consonant phonemes, i.e., sounds that make a difference in word meaning. The consonant system is characterized by the fact that besides a Dravidian inventory, it includes a number of features typical of Indo-Aryan languages. Below are some of the typical features:

- a contrast between apical and retroflex consonants, e.g., /ṱ/ – /ʈ/. Apical consonants are produced with the tip of the tongue touching the roof of the mouth, whereas retroflex consonants are produced with the tongue curled, so that its underside comes in contact with the roof of the mouth;
- a contrast between plain and aspirated stops;
- limited occurrence of consonant clusters in final position.
- gemination, or doubling, of consonants. (doubled).

		Bilabial	Labiodental	Apicodental	Alveolar	Retroflex	Palato-alveolar	Velar	Glottal
Stops	**voiceless plain/aspirated**	**p p^h**		**t̪ t̪ t̪**		**ʈ $ʈ^h$**		**k k^h**	
	voiced plain/aspirated	**b b^h**		**d̪ $d̪^h$**		**ɖ $ɖ^h$**		**g g^h**	
Fricatives	**Voiceless**		**F**		**s (z)***	**ʂ**	**ʃ**		**h**
Affricates	**voiceless/voiced ʧ and ʤ**					**xx**	**c ɟ**		
Nasals		**m**		**n̪**		**ɳ**	**ɲ**	**Ŋ**	
Trill					**r**				
Laterals				**l̪**		**ɭ**			
Approximants			**ʋ**	**.xx**			**j**		

- /ʈ, ɖ, ɳ, ʂ, ɭ, ɻ/ are retroflex consonants with no equivalents in English
- /t̪, d̪, n̪, l̪ / are pronounced with the tip of the tongue touching the back of the front teeth
- ʃ = *sh* in *shop*
- /c/ = *ch* in *chop*
- *z occurs only in borrowed words
- /ɟ/ = *j* in *jobq*
- /ɲ/ = first *n* in *canyon*
- /ŋ/ = *ng* in *song*
- /ʋ/ has no equivalent in English
- /j/ = *y* in *yet*

Reference

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Modern Kannada Inventory of Consonants and Vowels (Campbell & Moseley, 2012)

CONSONANTS

ಕ	ಖ	ಗ	ಘ	ಙ
ka	*kha*	*ga*	*gha*	*nga*
ಚ	ಛ	ಜ	ಝ	ಞ
ca	*cha*	*ja*	*jha*	*nya*
ಟ	ಠ	ಡ	ಢ	ಣ
ṭa	*ṭha*	*ḍa*	*ḍha*	*ṇa*
ತ	ಥ	ದ	ಧ	ನ
ta	*tha*	*da*	*dha*	*na*
ಪ	ಫ	ಬ	ಭ	ಮ
pa	*pha*	*ba*	*bha*	*ma*
ಯ	ರ	ಲ	ವ	
ya	*ra*	*la*	*va*	
ಶ	ಷ	ಸ	ಹ	ಳ
śa	*ṣa*	*sa*	*ha*	*ḷa*

VOWELS

ಅ	ಆ	ಇ	ಈ	ಉ	ಊ	ಋ
a	*ā*	*i*	*ī*	*u*	*ū*	*ru*
ಎ	ಏ	ಐ	ಒ	ಓ	ಔ	
e	*ē*	*ai*	*o*	*ō*	*au*	

Vowel signs: here illustrated as applied to *ka*:

ಕಾ *kā*, ಕಿ *ki*, ಕೀ *kī*, ಕು *ku*, ಕೂ *kū*, ಕೃ *kru*, ಕೆ *ke*,
ಕೇ *kē*, ಕೈ *kai*, ಕೊ *ko*, ಕೋ *kō*, ಕೌ *kau*

Reference

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Appendix 2

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

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

Appendix 3

WHO THE TEN QUESTIONS SCREEN (Malhi & Singhi, 2002)

1. Compared with other children, did the child have any serious delay in sitting, standing or walking?
2. Compared with other children does the child have difficulty seeing, either in the daytime or at night?
3. Does the child appear to have difficulty hearing?
4. When you tell the child to do something, does he/she seem to understand what you are saying?
5. Does the child have difficulty in walking or moving his/her arms or does he/she have weakness and/or stiffness in the arms or legs?
6. Does the child sometimes have fits, become rigid, or lose consciousness?
7. Does the child learn to do things like other children his/her age?
8. Does the child speak at all (can he/she make himself/herself understood in words; can he/she say any recognizable words)?
9. For 3 to 9 year olds ask: Is the child's speech in any way different from normal (not clear enough to be understood by people other than his/her immediate family)? For 2 year olds ask: Can he/she name at least one object (for example, an animal, a toy, a cup, a spoon)?
10. Compared with other children of his/her age, does the child appear in any way mentally backward, dull or slow?

Appendix 4

Screening for Central Auditory Processing (SCAP)

Yathiraj and Mascarenhas (2003)

Sl. No.	Questions	Yes	No
1.	Does not listen carefully and does not pay attention (requires repetition of instruction)		
2.	Has short attention span of listening (approx. 5-15 min)		
3.	Easily distracted by background sound		
4.	Has trouble in recalling what has been heard in the correct order		
5.	Forgets what is said in few minutes		
6.	Has difficulty in differentiating one speech sound from other similar sound		
7.	Has difficulty in understanding verbal instruction and tend to misunderstand what is said which other children of the same age would understand		
8.	Show delayed response to verbal instructions or questions		
9.	Has difficulty in relating what is heard with what is seen		
10.	Poor performance in listening task, but performance improves with visual cues		
11.	Has pronunciation problems (mispronunciation of words)		
12.	Performance is below average in one or more subjects, such as social subjects, I/II language		

Appendix 5

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 6

Examples of error words in participants

Target sound	Target word	Glossary	Erred production*
/ʈ/	/ ʈapa:lu/	Rack to keep books	/ tapa:lu/
	/gaʈʈi/	Strong	/gatti/
/ɖ/	/ ɖabbi/	Box	/ dabbi/
	/baɖava/	Poor man	/badava/
/ɳ/	/kaɳɳu/	Eye	/kannu/
	/gaɳapa/	A Hindu God name	/ganapa/
/ɭ/	/keɭage/	Down	/kelage/
	/biɭi/	White	/bili/

*****All these retroflexes are substituted by dental sounds.

Appendix 7

Number of opportunities for each target phoneme in a particular phonetic context across the two articulation tests

		/a/			/i/			/u/		
		KDPAT	**DTA**	**Total**	**KDPAT**	**DTA**	**Total**	**KDPAT**	**DTA**	**Total**
/ɖ/	**Initial**	2	2	**4**	0	1	**1**	0	1	**1**
	Medial	1	2	**3**	1	1	**2**	0	1	**1**
	Total	**3**	**4**	**-**	**1**	**2**	**-**	**0**	**2**	**-**
/ʈ/	**Initial**	0	0	**0**	0	0	**0**	0	0	**0**
	Medial	1	0	**1**	0	0	**0**	0	0	**0**
	Total	**1**	**0**	**-**	**0**	**0**	**-**	**0**	**0**	**-**
/k/	**Initial**	2	0	**2**	0	0	**0**	0	0	**0**
	Medial	1	0	**1**	0	0	**0**	1	0	**1**
	Total	**3**	**0**	**-**	**0**	**0**	**-**	**1**	**0**	**-**
/g/	**Initial**	2	2	**4**	0	2	**2**	0	2	**2**
	Medial	0	2	**2**	0	2	**2**	1	2	**3**
	Total	**2**	**4**	**-**	**0**	**4**	**-**	**1**	**4**	**-**
/c/	**Initial**	2	2	**4**	0	2	**2**	0	2	**2**
	Medial	2	2	**4**	0	2	**2**	0	2	**2**
	Total	**4**	**4**	**-**	**0**	**4**	**-**	**0**	**4**	**-**
/ɟ/	**Initial**	1	2	**3**	1	2	**3**	0	2	**2**
	Medial	1	2	**3**	1	2	**3**	0	2	**2**
	Total	**2**	**4**	**-**	**2**	**4**	**-**	**0**	**4**	**-**
/s/	**Initial**	0	2	**2**	1	2	**3**	0	2	**2**
	Medial	0	2	**2**	0	2	**2**	1	2	**3**
	Total	**0**	**4**	**-**	**1**	**4**	**-**	**1**	**4**	**-**
/ɳ/	**Medial**	0	2	**2**	0	2	**2**	1	2	**3**
/ɭ/	**Medial**	0	1	**1**	1	1	**2**	0	1	**1**

*To equalize the number of stimuli words were also considered from mid-session wordlist especially for retroflex /ʈ/ and velar /k/

Appendix 8

Stimuli words for pre-post therapy assessments with glossary

		/a/	Gloss	/i/	Gloss	/u/	Gloss
/ɖ/	Initial	/ɖabbi/	Box	/ɖikki/	Dash	/ɖubba/	Bump
		/ɖa:bu/	An ornament	/ɖipo/	Dipo	/ɖumma/	Fat
	Medial	/baɖava/	Poor	/gaɖija:ra/	Clock	/ceɳɖu/	Ball
		/o: ɖa:ʈa/	Walk-run	/aŊgaɖi/	Shop	/laɖɖu/	Sweet
/ʈ/	Initial	/ʈapa:lu/	File	/ʈi:carru/	Teacher	/ʈuɖe/	Today
		/ʈa:rcu/	Torch	/ʈikki/	A dish	/ʈuma:ro/	Tomorrow
	Medial	/aʈʈa/	Attic	/haʈʈi/	Hut	/kunʈu/	Skip
		/kiʈaki/	Window	/gaʈʈi/	Strong	/caukaʈʈu/	Border
/k/	Initial	/kallu/	Stone	/kiɖi/	Spark	/kuɭɭa/	Short
		/kavi/	Poet	/kiccu/		/kusuma/	Flower
	Medial	/pukka/	Feather	/mikki/	Mickey	/ɖoŊku/	Bent
		/makkaɭu/	Children	/hakki/	Bird	/tukku/	Rust
/g/	Initial	/gaɳapa/	God name	/giɖa/	Plant	/gula:bi/	Rose
		/ga:ɭipaʈa/	Kite	/gi:ʈu/	Line	/gu:ɖu/	Nest
	Medial	/agasa/	Washerman	/taŊgi/	Younger sister	/haɖagu/	Ship
		/baŊga:ri/	Sweet	/saŊgi:ta/	Classical music	/ha:gu/	Also
/ʧ/	Initial	/caraka/	Charaka	/cilaka/	Lock	/cukke/	Dot
		/ca:pe/	Mat	/ci:la/	Gunny bag	/cu:ru/	Little
	Medial	/camaca/	Spoon	/ʃuci/	Clean	/honcu/	Spy
		/sama:ca:ra/	News	/kaici:la/	Gunny bag	/accu/	Mold
/ʤ/	Initial	/ɟaja/	Win	/ ɟiŊke/	Deer	/ɟuŊgu/	
		/ ɟa:ɳa/	Good	/ɟi:va/	Life	/ɟu: ɟu/	Cards
	Medial	/niɟa/	Truth	/hu: ɟi/	Jug	/ra: ɟu/	Name
		/haɟa:ra/	Varanda	/ra: ɟi:va/	Name	/ka: ɟu/	Cashew
/s/	Initial	/sanɟe/	Evening	/sikki/	To meet	/sutta/	Surrounding
		/sa:la:gi/	In line	/si:re/	Saree	/su: ɟi/	Needle
	Medial	/basava/	Bull	/bisilu/	Sunny	/hasu/	Cow
		/masa:le/	Spices	/masi:di/	Mosque	/bassu/	Bus
/ɳ/	Medial	/gaɳapa/	God name	/beraɳi/	Cow dung	/aɳu/	A measure
		/pariɳa:ma/	Consequences	/ramaɳi:ja/	Beautiful	/kaɳɳu/	Eyes
/ɭ/	Medial	/keɭage/	Down	/biɭi/	White	/a:kaɭu/	Calf
		/kaɭɭa/	Thief	/ko: ɭi/	Cock	/eɭɭu/	Til

Note: There are two stimuli under each context

Appendix 9

Intervention stimuli with glossary

		/a/	Gloss	/i/	Gloss	/u/	Gloss
/ɖ/	**Initial**	/ɖabbi/	Box	/ɖikki/	Dash	/ɖummu/	Fat
		/ɖamaru/	Pellet drum	/ɖimpal/	Dimple	-	
		/ɖasʈbin/	Dustbin	/ɖipo/	Dipo	-	
	Medial	/gaɳɖasu/	Man	/aŊgaɖi/	Shop	/uɖupu/	Dress
		/giɖɖa/	Short	/kaɖɖi/	Stick	/paɖɖu/	A food item
		/gaɖɖa/	Beard	/maɳɖi/	Knee	/laɖɖu/	A sweet
/ʈ/	**Initial**	/ʈaval/	Towel	/ʈivi/	Television	/ʈu/	Two
		/ʈagaru/	Billy goat	/ʈippu/	A warrior	/ʈu:t/	Tooth
		/ʈa:Ŋku/	Tank	/ʈiphannu/	Tiffan	/ʈu:ru/	Tour
	Medial	/paʈa/	Kite	/tuʈi/	Lips	/eɳʈu/	Eight
		/baʈʈalu/	Bowl	/buʈʈi/	Basket	/uppiʈʈu/	A food item
		/gaŊʈalu/	Throat	/siʈi/	City	/boʈʈu/	Bindi
/k/	**Initial**	/kappe/	Frog	/kivi/	Ears	/kudure/	Horse
		/kapi/	Monkey	/kiɳɖi/	Hole	/kulphi/	Kulfi
		/kabbu/	Sugarcane	/kittu/	Pluck	/kuɖi/	Drink
	Medial	/akka/	Elder sister	/akki/	Rice	/bukku/	Book
		/pukka/	Feather	/cikki/	A sweet	/bekku/	Cat
		/takkaɖi/	Weighing machine	/ɟumuki/	Ear ring	/cakkuli/	A food item
/g/	**Initial**	/gadde/	Fields	/gilaki/	Rattle	/gubbi/	Sparrow
		/gammu/	Gum	/giɖa/	Plant	/gula:bi/	Rose
		/gaɳʈe/	Bell	/giɳi/	Parrot	/guddali/	Pickaxe
	Medial	/agasa/	Washerman	/aŊgi/	Shirt	/magu/	Baby
		/laŊga/	Long skirt	/huɖugi/	Girl	/teŊgu/	Coconut
		/maŊga/	Monkey	/maggi/	Mathematics tables	/malagu/	Sleep
/ʧ/	**Initial**	/ʧappali/	Slipper	/cippu/	Coconut shell	/cukki/	Dot
		/ʧapa:ti/	Chapathi	/ʧinna/	Gold	/ʧu:ru/	Piece
		/ʧanda/	Nice	/ʧiʈʈe/	Butterfly	/ʧu:pu/	Sharp
	Medial	/manʧa/	Cot	/kurʧi/	Chair	/kaʧʧu/	Bite
		/kiʧaɖi/	A food item	/paʧʧi/	Flat stone	/aʧʧu/	Mold
		/baʧʧalu/	Bathroom	/karʧiphu/	Kerchief	/benʧu/	Bench
/ʤ/	**Initial**	/ʤana/	People	/ʤiŊke/	Deer	/ʤubba/	A men's wear
		/ ʤaɖe/	Hair plat	/ʤiɖɖu/	Oily	/ʤuʈʈu/	Pony
		/ ʤaɭaka/	Bath	/ʤiraɭe/	Cockroach	/ʤu:su/	Juice
	Medial	/aʤʤa/	Grandfather	/aʤʤi/	Grandmother	/uʤʤu/	Rub
		/maʤa/	Enjoy	/maʤʤige/	Curd milk	/boʤʤɟɟu/	Body fat

		/gaʤa/	Elephant	/baʤʤi/	A food item	/goʤʤu/	A food item
/s/	**Initial**	/santé/	Market	/sinema/	Cinema	/suma/	Flower
		/sampige/	A flower name	/simha/	Lion	/suraŊga/	Tunnel
		/sakkare/	Sugar	/siʈʈu/	Anger	/suttu/	Turn-around
	Medial	/kasa/	Dirt	/hasiru/	Green	/hasu/	Cow
		/mosaru/	Curd	/masi/	Greese	/bassu/	Bus
		/hamsa/	Swan	/ta:rasi/	Rooftop	/halasu/	Jackfruit
/ɳ/	**Medial**	/saɳɳa/	Thin	/maɳi/	Pearl	/maɳɳu/	Mud
		/baɳɳa/	Colour	/kaɳive/	Canal	/haɳɳu/	Fruit
		/haɳa/	Money	/kiŊkiɳi/	Anklet	/kaɳɳu/	Eyes
/ɭ/	**Medial**	/haɭɭa/	Pit	/baɭɭi/	Creeper	/huɭu/	Insect
		/haɭadi/	Yellow	/haɭɭi/	Village	/haraɭu/	Gem stone
		/kaɭɭa/	Thief	/kuɭɭi/	Short girl	/muɭɭu/	Thorn

Continuous assessment stimuli with glossary

		/a/	**Gloss**	**/i/**	**Gloss**	**/u/**	**Gloss**
/ɖ/	**Initial**	/ɖasʈar/	Duster	/ɖisko/	Disco	/ɖubba/	Bump
		/ɖakke/	An instrument	/ɖiʃum/	Punch	-	-
		/ɖaŊgu:ra/	An instrument	/ɖi:zallu/	Diesel	-	-
	Medial	/daɖɖa/	Simpleton	/kannaɖi/	Mirror	/duɖɖu/	Money
		/vaɖɖa/	Rude	/caɖɖi/	Underwear	/hiɳɖu/	Squeeze
		/paɳɖari/	A name	/tiɳɖi/	Breakfast	/guɖugu/	Thunder
/ʈ/	**Initial**	/ʈapa:lu/	Shelf	/ʈi:car/	Teacher	/ʈuɖe/	Today
		/ʈa:rcu/	Torch	/ʈikeʈʈu/	Ticket	/ʈuma:ro/	Tomorrow
		/ʈasse/	Seal	/ʈikki/	A food	/ʈuk/	Took
	Medial	/aʈʈa/	Attic	/roʈʈi/	Roti	/guʈʈu/	Secret
		/koʈaɖi/	Room	/gaʈʈi/	Hard	/kuɳʈu/	Skip
		/kiʈaki/	Window	/haʈʈi/	Hut	/caukaʈʈu/	Border
/k/	**Initial**	/kallu/	Stone	/kiɖi/	Spark	/kuɭɭa/	Short boy
		/kattu/	Neck	/kiccu/	Blaze	/kuri/	Sheep
		/kavi/	Poet	/kiri/	Small	/kusuma/	Flower
	Medial	/pukka/	Feather	/hakki/	Bird	/dikku/	Direction
		/makkaɭu/	Children	/mikki/	Mickey	/ɖoŊku/	Bent
		/cikka/	Small	/buraki/	Crying kid	/tukku/	Rust
/g/	**Initial**	/gari/	Feather	/giʈa:ru/	Guitar	/guhe/	Den
		/galla/	Chin	/giri/	Peak	/guɖisu/	Sweep
		/gandha/	Sandal	/giɳɳu/	A sweet	/guɳisu/	Multiply
	Medial	/magaɭu/	Daughter	/ɟigi/	Jump	/nagu/	Smile

		/aŊga/	Body part	/taŊgi/	Younger sister	/nuŊgu/	Swallow
		/saŊga/	Togetherness	/tirugi/	Turn	/karagu/	Melt
/ʧ/	**Initial**	/ʧaraɳɖi/	Drainage	/ʧikka/	Small	/ʧu:ʈi/	Active
		/ʧaɭi/	Cold	/ʧitta/	Mind	/ʧurku/	Smart
		/ʧappara/	Shelter	/ʧimmu/	Sprinkle	/ʧuʈʈa/	
	Medial	/kavaʧa/	Kavach	/huʧʧi/	Mad	/henʧu/	Tile
		/lanʧa/	Bribe	/koʧʧi/	Cochin	/moʧʧu/	
		/paʧaɖi/	A food	/tarʧitu/	Scratch	/muʧʧu/	Close
/ʤ/	**Initial**	/ʤaʈaka/	Horse cart	/ʤira:phe/	Giraffe	/ʤu:n/	June
		/ʤala/	Water	/ʤigi/	Jump	/ʤugga/	
		/ʤari/	Rivulet	/ʤiɖɖu/	Stubborness	/ʤu:ʈu/	Jute
	Medial	/raʤa/	King	/saʤʤige/	A sweet	/ruʤu/	Sign
		/hunʤa/	Cock	/uʤʤi/	Rub	/uʤʤu/	Rub
		/vanaʤa/	Lotus	/kaʤʤi/	Rabies	/saʤʤu/	Decorate
/s/	**Initial**	/saɳɖige/	A food	/sippe/	Outer covering	/sukha/	Peace
		/sanɟe/	Evening	/simbi/	An ornament	/sundara/	Beautiful
		/sami:pa/	Near	/sipa:ji/	Soldier	/suta/	Son
	Medial	/rasa/	Juice	/hasi/	Fresh	/kanasu/	Dream
		/hesaru/	Name	/orasi/	Clean	/tusu/	A little
		/kamsa/	A mythological character	/masi/	Grease	/cessu/	Chess
/ɳ/	**Medial**	/saɳɳa/	Thin	/kaɳi/		/huɳɳu/	Ulcer
		/aɳɳa/	Elder brother	/dharaɳi/	Earth	/heɳɳu/	Woman
		/noɳa/	Housefly	/bharaɳi/	Pot	/giɳɳu/	A sweet
/ɭ/	**Medial**	/koɭa/	Pond	/taɭɭi/	Push	/araɭu/	Puffed paddy
		/daɭa/	Petal	/huɭi/	Sour	/eɭɭu/	Sesame
		/baɭapa/	Chalk	/kaɭɭi/	Thief	/teɭu/	Slim

Appendix 10

Example of analysis sheet

	Set1		Set2		Set3	
1.	ಕಪ್ಪೆ		ಕಬ್ಬು		ಪುಕ್ಕ	
2.	ಕಬ್ಬು		ಕಿವಿ		ಕಪ್ಪೆ	
3.	ಕಪಿ		ಕುದುರೆ		ಆಕಾಶ	
4.	ಕಿವಿ		ಕಪ್ಪೆ		ಕಿವಿ	
5.	ಕಿಂಡಿ		ಕಿಂಡಿ		ಅಕ್ಕಿ	
6.	ಕಿತ್ತು		ಕುಡಿ		ಲೀಕು	
7.	ಕುದುರೆ		ಕಪಿ		ಕುದುರೆ	
8.	ಕುಡಿ		ಕಿತ್ತು		ಬೆಕ್ಕು	
9.	ಕುಲ್ಫಿ		ಕುಲ್ಫಿ		ನೂಕು	
10.	ಪುಕ್ಕ		ಪುಕ್ಕ		ಕಬ್ಬು	
11.	ಅಕ್ಕ		ಅಕ್ಕಿ		ಅಕ್ಕ	
12.	ತಕ್ಕಡಿ		ಬೆಕ್ಕು		ಚಾಕು	
13.	ಅಕ್ಕಿ		ಅಕ್ಕ		ಕಿಂಡಿ	
14.	ಚಿಕ್ಕಿ		ಚಿಕ್ಕಿ		ಚಿಕ್ಕಿ	
15.	ಜುಮುಕಿ		ಬುಕ್ಕು		ಸೀಕಲು	
16.	ಬೆಕ್ಕು		ತಕ್ಕಡಿ		ಕುಡಿ	
17.	ಬುಕ್ಕು		ಜುಮುಕಿ		ಬುಕ್ಕು	
18.	ಚಕ್ಕುಲಿ		ಚಕ್ಕುಲಿ		ತೂಕ	
19.	ಆಕಾಶ		ಆಕಾಶ		ಕಪಿ	
20.	ಚಾಕು		ಲೀಕು		ತಕ್ಕಡಿ	
21.	ಪಟಾಕಿ		ನೂಕು		ಪಟಾಕಿ	
22.	ಲೀಕು		ಚಾಕು		ಕಿತ್ತು	
23.	ಸೀಕಲು		ಸೀಕಲು		ಜುಮುಕಿ	
24.	ಚೀಕು		ದೂಕು		ಚೀಕು	
25.	ನೂಕು		ಪಟಾಕಿ		ಕುಲ್ಫಿ	
26.	ತೂಕ		ಚೀಕು		ದೂಕು	
27.	ದೂಕು		ತೂಕ		ಚಕ್ಕುಲಿ	

Appendix 11

Number of articulatory intervention sessions per participant

Target phoneme	Participants	No. of intervention sessions	No. of mid-assessment sessions	Total number of intervention sessions
/k/	**SG**	15	5	20
	STG	4	1	5
	SU	3	1	4
	SH	6	1	7
	SB	12	3	15
	ST	12	3	15
/g/	**SG**	9	3	12
	SB	11	2	13
	SH	6	1	7
	ST	9	3	12
/ʈ/	**SJe**	9	3	12
	SR	6	2	8
	SH	18	5	23
	SB	14	3	17
	SJ	15	4	19
/ɖ/	**SJe**	9	3	12
	SR	11	3	14
	SH	6	1	7
	SB	8	1	9
	SJ	12	3	15
/ɳ/	**SJe**	5	1	6
	SHG	6	1	7
	SHV	4	1	5
	SJY	3	0	3
	SN	11	3	14
	SH	12	3	15
	SB	4	1	5
	SJ	14	4	18
/ɭ/	**SJe**	15	4	19
	SN	9	2	11
	SR	15	4	19
	SHV	3	1	4
/c/	**SHG**	5	1	6
	ST	5	1	6
/ɟ/	**SS**	6	2	8
	ST	3	1	4
	SR	6	1	7
/s/	**STG**	4	1	5
	SSA	6	1	7
	SS	6	2	8
Total		**337**	**86**	**423**