TEST BATTERY FOR PHONOLOGICAL REPRESENTATIONS IN KANNADA SPEAKING CHILDREN

A DOCTORAL THESIS

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CERTIFICATE

This is to certify that the thesis entitled **"Test Battery for Phonological Representations in Kannada Speaking Children"** submitted by Ms. Priya M. B. for the degree of Doctor of Philosophy (Speech Language Pathology) to the University of Mysore, Mysuru was carried out at the All India Institute of Speech and Hearing, Mysuru.

Place: Mysuru
Date: 28.07.2017

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CERTIFICATE

This is to certify that the thesis entitled **"Test Battery for Phonological Representations in Kannada Speaking Children"** submitted by Ms. Priya M. B. for the degree of Doctor of Philosophy (Speech Language Pathology) to the University of Mysore, Mysuru was carried out at the All India Institute of Speech and Hearing, Mysuru, under my guidance. I further declare that the results of this work have not been previously submitted for any other degree.

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DECLARATION

I declare that this thesis entitled **"Test Battery for Phonological Representations in Kannada Speaking Children"** submitted herewith for the award of degree of Doctor of Philosophy (Speech Language Pathology) to the University of Mysore, Mysuru is the result of work carried out by me at the All India Institute of Speech and Hearing, Mysuru, under the guidance of Dr. R. Manjula, Former Professor of Speech Pathology, All India Institute of Speech and Hearing, Mysuru. I further declare that the results of this work have not been previously submitted for any other degree.

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Abstract

Phonological representations contribute significantly to the development of oral language and emergent literacy skills. Deficit in various dimensions of phonological representations are reported to result in language and literacy difficulties in children with developmental disorders. Therefore, inclusion of phonological representations is an essential aspect of detailed phonological assessment. This is particularly important during the preschool years as there is considerable development in skills influenced by phonological representations during this period such as phonological awareness and reading. The differences in the phonological properties of languages demand assessment of the underlying phonological representations across various languages. Thus, this study aimed to develop and standardize a test battery to assess phonological representations in preschool children who are native speakers of Kannada language and also test for its clinical utility.

The test battery developed by the investigator included the following subsections: [1] Articulation Judgment Test for Vowels and Consonants [2] Articulation Correction Test for Vowels and Consonants [3] Sentence Imitation Test and [4] Rapid Automatized Naming for Nouns, Verbs and Size. The test battery was administered on 240 typically developing native speakers of Kannada in the age range of three to five years who were equally divided into four subgroups with an inter-age interval of 6 months. The effects of age, gender and stimuli were assessed on the performance of participants in various subsections of the test battery. In order to test the clinical utility of the test battery, the same was administered on 30 children with developmental disorders such as speech sound disorder, specific language *impairment, childhood apraxia of speech and at risk for dyslexia. The expressive language age of participants in the clinical group was in the range of three to five years. The performance of participants in the clinical group was compared to that of the typically developing group and also across the clinical groups.*

Results indicated significant effects of age and stimuli on the performance of typically developing participants in all subsections of the test battery. There was no significant effect of gender in any of the subsections. These findings indicating a developmental trend during the preschool years support the notion of emergent view of development of phonological representations. Performance of participants in the clinical group was significantly poorer compared to the typically developing group. Although a delay was evident, the group performance profiles were observed to have similar patterns across the clinical groups and typically developing group. Nevertheless, the test battery was found to be useful in assessing phonological representations in children with developmental disorders.

Key words: Phonological representations, Articulation Judgment, Articulation Correction, Sentence Imitation, Rapid Automatized Naming

INTRODUCTION

Acquisition of speech and language skills by a child is a stepping stone to success in various domains of his/her life such as cognitive, social, emotional and literacy among others. The process of acquisition of speech and language is a complex interplay of various skills including oral language, print awareness and phonological processing. Phonological processing refers to the use of sounds in a language or phonological information for speaking and reading purposes (Wagner & Torgesen, 1987). It is fundamental in the detection, identification and discrimination of individual speech sounds (Kidd, Shum, Ho, & Au, 2015). Phonological processing encompasses a cluster of three interlinked abilities namely, phonological awareness (awareness about the sound structures of a language), phonological retrieval or phonological recoding in lexical access (ability to recode written symbols into its lexical referent) and phonological short-term memory (ability to retain phonological information in working memory) (Wagner & Torgesen, 1987). These skills are integral to the development of good reading skills and are regarded as strong predictors of reading abilities (Snowling, 2000).

Pivotal to phonological processing is the concept of *Phonological Representations* which refers to the sound-based codes about phonological information of words stored in the long term memory of an individual (Stackhouse & Wells, 1997). The quality of phonological representations is crucial in determining individual differences in phonological processing abilities (Claessen, Heath, Fletcher, Hogben, & Leitão, 2009; Elbro & Jensen, 2005). Phonological representations have a quintessential role both in the development of speech in the early years of life as well as emergent literacy (Fowler, 1991; Metsala & Walley, 1998; Swan & Goswami, 1997). Sumner (2003) stated that the construct of phonological representations helps to characterize generalizations about behaviors and lexical organization which are otherwise difficult to measure. Phonological representations of words must be sufficiently distinct to allow a child to match speech sounds heard in conversation with the respective sound patterns encoded previously. Thus, the effects of acoustic variability often observed both within and between speakers of the same language are minimized.

Phonological representations are described at three levels namely acoustic, linguistic and cognitive (Goswami, 2012). Phonological representations at the acoustic level are described based on the extraction of acoustic parameters such as pitch, loudness and duration. At the linguistic level, the phonological representations are studied based on the constraints on speech production system imposed by the vocal tract in terms of place of articulation, manner of articulation etc. At the cognitive level, phonological representations are described with respect to the constituent elements such as vowels and consonants. Owing to the abstract nature of the phoneme, a reliable direct mapping between the acoustic, and linguistic or cognitive levels is rendered difficult and challenging. Given that speech perception is plausible even in the absence of specific formant structures, it was posited that phonological representations are multisensory in nature encompassing numerous levels of acoustic and temporal information.

Development of phonological representations in children are extensively researched and documented, particularly during infancy and early childhood. The theoretical perspectives on development of phonological representations can be broadly classified into two categories: (a) the accessibility view and (b) the emergent view (for a review, see Walley, Metsala, & Garlock, 2003). According to accessibility view, the lexicon of children consists of fine-grained representations of phonemic structures of words in a highly modularized manner right from birth. The proponents of this school of thought suggest that infants have segmented adult-like phonological representations from the beginning. However, they are explicitly accessed by children after being exposed to literacy or with adequate metacognitive abilities (Liberman, Shankweiler, & Liberman, 1989; Morais, Bertelson, Cary, & Alegria, 1986). This theoretical perspective has gained credibility from studies on infant speech perception revealing sensitivity of very young infants to minimal contrasts in speech (e.g., Bailey & Plunkett, 2002; Ballem & Plunkett, 2005; Swingley, 2009; Swingley & Aslin, 2000, 2002) and drastic improvements in the performance of school children on phoneme awareness tasks consequent to literacy exposure (Ziegler & Goswami, 2005).

The proponents of emergent view of development of phonological representations on the other hand, believe that early representations in children are holistic and underspecified. These are gradually refined with the addition of phonological information associated with increase in vocabulary (Fowler, 1991; Metsala & Walley, 1998; Walley, 1993). The premise of emergent view is that the early vocabulary of children is limited and hence, discrimination among the known words does not require storage of detailed phonological representations. As vocabulary continues to develop, the phonological representations undergo gradual refinement in order to efficiently discriminate between speech sounds.

There are several theories of development of phonological representations proposed under the emergent view. According to the 'Lexical Restructuring Hypothesis' (Metsala & Walley, 1998), the earliest linguistic representations in a developing child are holistic in nature which are progressively segmented with increase in vocabulary to enable processing of phonological information at various levels – syllable, onset-rime and phoneme (Fowler, 1991). The process of lexical restructuring is an important prerequisite for the development of phonological awareness skills which in turn are the building blocks of early literacy skills. On the other hand, the proponents of Psycholinguistic Grain Size theory (Ziegler & Goswami, 2005) argue that although a spurt in vocabulary facilitates segmentation of phonological representations for large units, phonemic representations are a consequence of acquisition of literacy or direct instructions in phoneme grapheme correspondence.

One of the recent models encompassing components of both the accessibility and the emergent view of phonological representations is 'PRIMIR (Processing Rich Information from Multidimensional Interactive Representations)' put forth by Werker and Curtin (2005). Contradicting reports on phonological specificity in young infants based on the task used led to the development of PRIMIR (Swingley & Aslin, 2002; Werker, Fennell, Corcoran, & Stager, 2002). PRIMIR proposes a developmental framework suggesting that rich, detailed information from the input speech signal is stored from infancy in multidimensional interactive planes. However, accessibility to specific information is a function of filtering action depending on the child's developmental level and task demands.

Development of phonological representations in typically developing children is documented by researchers from different perspectives. Factors such as increase in receptive vocabulary (Befi-Lopes, Pereira, & Bento, 2010; Gray, 2004; Metsala & Walley, 1998), early literacy skills (Bishop & Snowling, 2004; Elbro, Nielsen, & Petersen, 1994; Sutherland & Gillon, 2007), feedback between acoustic and articulatory representations and early onset of babbling and vocal imitation (Plaut & Kello, 1999) are suggested as having significant influence in the development and segmentation of phonological representations.

Poor or underspecified phonological representations and its effects on spoken and written language are also reported in children with a variety of developmental disorders. Deficits in phonological representations are professed to be the cause of language and literacy difficulties of children with Speech Sound Disorders (Anthony et al., 2011), Specific Language Impairment (SLI) (Elliott, Hammer, & Scholl, 1990; Leonard & Eyer, 1996; Stark & Heinz, 1996; Tallal, 1990), Childhood Apraxia of Speech (CAS) (Gillon & Moriarty, 2007; Marquardt, Sussman, Snow, & Jacks, 2002; McNeill, Gillon, & Dodd, 2009) and Dyslexia (Bortolini & Leonard, 2000; Gathercole & Baddeley, 1990; Swan & Goswami, 1997).

Given the crucial role of phonological representations in the development of oral language and emergent literacy skills, assessment of phonological representations in young children becomes imperative. Several tasks have been used to measure phonological representations in both typically developing children and children with developmental disorders. Production based tasks like picture naming (Bridgeman & Snowling, 1988; Elbro, Rasmussen, & Spelling, 1996; Foy & Mann, 2001; Roberts, 2005), word and nonword imitation (Fowler & Swainson, 2004), gating paradigm (Dollaghan & Campbell, 1998; Metsala, 1997a, 1997b); correcting mispronunciations (Anthony et al., 2010; Fowler & Swainson, 2004; Foy & Mann, 2001) and sentence imitation (Andrews & Fey, 1986; Anthony et al., 2010) have been increasingly used to measure phonological representations in children. The limited usefulness of production tasks in children with expressive speech impairments led to the development of receptive tasks to gain insights into phonological representations. Tasks such as articulation judgment (Anthony et al; 2010; Carroll & Snowling, 2004; Mani & Plunkett, 2007; Rvachew, Ohberg, Grawburg, & Heyding, 2003; Sutherland & Gillon, 2005), choosing the most accurate pronunciation among several tokens (Fowler & Swainson, 2004); picture based speech discrimination tasks (e.g., Elbro & Petersen, 2004; Foy & Mann, 2001) and lexical decision (Claessen et al., 2009) have been frequently used as receptive tasks to avoid the confounding effects of poor speech output in the measurement of phonological representations.

Need for the Study

In the past, issues related to phonological representations were often inferred based on studies that included tasks to tap infant speech perception, speech production, phonological awareness, early literacy, reading and writing. However, researchers have shown that the quality of phonological representations can be best assessed directly using tasks such as speech gating, lexical judgment, and nonword repetition among others rather than being inferred indirectly on the basis of phonological processing tasks (e.g., Kidd et al., 2015). The data with respect to phonological representation in young infants is abundant but is limited in pre-school children.

Preschool period is an intermediate period that extends beyond infancy but precedes children's exposure to formal literacy instruction and is therefore, of particular theoretical interest. The preschool years are crucial because the phonological awareness and literacy development in these years are heavily influenced by the processing of phonological representations (Elbro, Borstrom, & Petersen, 1998; McCardle, Scarborough, & Catts, 2001; Vihman & Croft, 2007). Metalinguistic tasks which can provide some insight about the underlying representations develop only towards the end of preschool and thus, the use of metalinguistic tasks in preschool children is restricted. Phonological awareness tasks are literacy dependent and hence may not be ideal to infer about phonological representations during the preschool years. The extent of lexical differentiation has been hypothesized to be a potential measure as it is less dependent on literacy knowledge (Fowler, 1991; Gathercole, 1995; Metsala, 1997a). Ainsworth, Welbourne, and Hesketh (2016) studied phonological representations in children aged 3;6 to 4;6 years and provided evidence of restructuring and hence, developmental trends in phonological representations in preschool children.

The influence of one's oral language on acquisition of different levels of phonological awareness has been widely researched and evidenced in the literature (Anthony & Francis, 2005; Caravolas & Bruck, 1993; Cossu, Shankweiler, Liberman, Katz, & Tola, 1988; Demont & Gombert, 1996; Durgunoglu & Oney, 1999). Similarly, the influence of oral language on the organization of one's phonological system has also been studied. There is a need to identify which tasks best reflect the underlying phonological representations in a given language, in order to facilitate understanding of language specific/ universal factors that contribute to phonological representations skills (Anthony et al., 2011; Caravolas & Bruck, 1993).

The phonological properties of English and Kannada (a Dravidian language spoken majorly in the Karnataka State of South India) are very different, and are attributed to differences in terms of word length, syllable shape, consonant clusters and word neighborhood effects. Among the many differences in the two languages, the difference in the proportion of mono-, bi- and multisyllabic words in the two languages are dominant. The proportion of monosyllabic words in English is far greater than bi- and multisyllabic words (Caravolas, 1993). Caravolas (1993) reported that the proportion of monosyllabic words when compared to bisyllabic words in English is 3.5:1. On the other hand, Kannada majorly consists of bi-, tri- and multisyllabic words whereas monosyllabic words are rare (Nag-Arulmani, Reddy, & Buckley, 2003).

There are evident differences in the intrasyllabic structure of English and Kannada. Kannada has a simple CVCVCV word structure where C stands for Consonant and V for Vowel. The syllables in Kannada may have a V, CV, CCV or CCCV (mainly in borrowed words) structure whereas English is ambisyllabic and the frequency of CVCVCV word structures is significantly lower. This leads to clear and obvious syllable boundaries in Kannada. Nag-Arulmani et al. (2003) analyzed the percentage of different word structures in English and Kannada and reported that: (a) words with simple CV clusters were found to be 16% in English and 42% in Kannada, (b) words with a combination of simple CV and CCV clusters were found to be 24% in English and 42% in Kannada, (c) words with VC and VCC endings were found to be 24% and 28% in English, but none in Kannada.

Related to the feature of syllabic structure of the Kannada and English languages is the open and closed endedness of words. Most words in Kannada language are open syllables with the exception of words borrowed from other languages. In contrast, most words in English language are closed ended (Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995). However, the influence of other languages on Kannada is such that closed-syllable words found in borrowed words usually have a vowel added and converted into open syllable words. These differences demonstrate the importance of examining phonological representation across languages to understand both the language specific and the universal factors that contribute to phonological representation skills.

Native speakers of Kannada who are admitted to schools with English as the medium of instruction are first exposed to English most often in the school environment. These children are considered as incipient Kannada-English bilinguals (on the lines of Anthony et al., 2010) referring to native speakers of Kannada who experience increased opportunities and the need to communicate in English as well. It would be of interest to study the phonological representations of this population in the context of oral language. The findings would facilitate further understanding of the underlying phonological representations in the native language (Kannada) of the incipient Kannada-English bilinguals.

Given that poor phonological representations and/or access to it are at the core for many developmental disorders such as Speech Sound Disorder, Specific Language Impairment, Childhood Apraxia of Speech and Dyslexia, it is important that phonological representations be assessed in these children at an early stage to facilitate a holistic approach in intervention. Availability of a common tool to assess phonological representation in these different groups of children further facilitates a direct comparison between these conditions. Thus, there is a need to develop a test battery to assess phonological representations in children and to examine its utility in clinical population.

Aims of the study

The study aimed to develop and standardize a test battery for the assessment of phonological representations in typically developing native speakers of Kannada in the age range of 3-5 years. Further, to test the utility of the battery in assessing phonological representations in clinical population, it was administered on few groups of children with developmental disorders.

Objectives of the study

I. To investigate and study the following in typically developing native speakers of Kannada in the age range of 3-5 years:

1. The effect of gender on the performance in each of the following tasks:

    A. Articulation Judgment Test for: a) Vowels & b) Consonants

    B. Articulation Correction Test for: a) Vowels & b) Consonants

    C. Sentence Imitation Test

    D. Rapid Automatized Naming Test for: a) Nouns b) Verbs & c) Size

2. The effect of age on the performance in each of the following tasks:

    A. Articulation Judgment Test for: a) Vowels & b) Consonants

    B. Articulation Correction Test for: a) Vowels & b) Consonants

    C. Sentence Imitation Test

    D. Rapid Automatized Naming Test for: a) Nouns b) Verbs & c) Size

3. The effect of stimuli on the performance in each of the following tasks:

    A. Articulation Judgment Test

    B. Articulation Correction Test

    C. Sentence Imitation Test

    D. Rapid Automatized Naming

II. To investigate and compare the performance of children with the following developmental disorders with that of the typically developing children in various subsections of the test battery:

    A. Children with Speech Sound Disorder (SSD)

    B. Children with Specific Language Impairment (SLI)

    C. Children with Childhood Apraxia of Speech (CAS)

    D. Children at risk for Dyslexia

Hypotheses

The following Null hypotheses were assumed for the study:

1. There is no significant effect of gender on tasks tapping phonological representations in the test battery, viz., the Articulation Judgment Test for Vowels and Consonants, Articulation Correction Test for Vowels and Consonants, Sentence Imitation Test and Rapid Automatized Naming

Test (Nouns, Verbs and Size) in Kannada speaking typical children between three to five years of age.

2. There is no significant effect of age on tasks tapping phonological representations in the test battery, viz., the Articulation Judgment Test for Vowels and Consonants, Articulation Correction Test for Vowels and Consonants, Sentence Imitation Test and Rapid Automatized Naming Test (Nouns, Verbs and Size) in Kannada speaking typical children between three to five years of age.
3. There is no significant effect of stimuli on the Articulation Judgment Test, Articulation Correction Test, Sentence Imitation Test and Rapid Automatized Naming Test in Kannada speaking typical children between three to five years of age.
4. There is no significant difference between Kannada speaking typically developing children in the age range of three to five years and children with developmental disorders [Children with Speech Sound Disorder (SSD), Specific Language Impairment (SLI), Childhood Apraxia of Speech (CAS) and Children at risk for Dyslexia] matched for expressive language abilities in performance on the test battery for phonological representations.

Method

Participants

Two groups of participants were included in the study.

1. *Typically Developing Group*

   Typically developing children in the age range of 3-5 years who were native speakers of Kannada language residing in the city of Mysuru, Karnataka were recruited for the study. A total of 240 participants were included who were further divided into four subgroups with an interage interval of 6 months. Each subgroup included sixty children (30 boys; 30 girls). The participants were initially screened to rule out any organic, behavioral, emotional and sensory impairment using the WHO Ten Question Disability Screening Checklist (Singhi, Kumar, Prabhjot & Kumar, 2007). Participants who fulfilled the selection criteria were included in the study.

2. *Clinical Group*

   A total of 30 children with developmental disorders with an expressive language age in the range of 3-5 years were also recruited to check for the clinical utility of the test battery developed and standardized on typically developing children. Children with a clinical diagnosis of Speech Sound Disorder (11), Specific Language Impairment (9), at risk for Dyslexia (7) and Childhood Apraxia of Speech were included in the Clinical Group.

Procedure

The study was carried out in 5 phases:

Phase 1 Development of test battery for the assessment of phonological representations in typically developing native speakers of Kannada in the age range of 3-5 years.

Phase 2 Conduct Pilot study

Phase 3 Modification of the test battery based on the results of pilot study

Phase 4 Standardization of the test battery by administering on participants in the typically developing group.

Phase 5 Administration of the test battery on participants in the clinical groups to test for its utility.

An assessment tool titled "Test Battery for Phonological Representations in Kannada Speaking Children" was compiled and developed by the investigator based on several sources cited in the literature. The subsections included in the battery are:

1. Articulation Judgment Test for Vowels and Consonants,
2. Articulation Correction Test for Vowels and Consonants,
3. Sentence Imitation Test and
4. Rapid Automatized Naming Test for Nouns, Verbs and Size.

The subsections and the stimuli for each subsection of the test battery were designed as deemed appropriate for native speakers of Kannada in the age range of 3-5 years. The word lists developed were initially presented to children in the age range of >3;0 - ≤ 3;6 years, this being the youngest group of participants of the study in order to check for familiarity. Based on the responses, the stimuli were shortlisted and presented to adult native speakers of Kannada to rate for familiarity and appropriateness of the stimulus as well as ambiguity of the pictures developed to represent the words. The sentence stimuli used in the study were also rated by the adult speakers for familiarity and appropriateness.

A pilot study was carried out before finalizing the test battery in order to verify the appropriateness of the material developed, instructions given, response recording and scoring procedures. The test battery was pilot tested on 24 typically developing children in the age range of 3-5 years. Based on the results of the pilot study, suitable modifications were incorporated in the assessment tool and the test battery for phonological representations for Kannada speaking children was finalized. The final test battery is given in Appendix 2.

The test battery was then administered on 240 participants in the typically developing group and 30 participants in the clinical group. Typically developing children were assessed in a quiet environment in the school set up whereas those in the clinical group were tested in the clinical settings. The time taken for administering the test battery on each participant was about 2.5 hours approximately. The responses of the participants on various subsections of the test battery were analyzed and scored appropriately. Inter- and intra- judge reliability measures were established for the administration of the tests in the battery. Suitable statistical analyses were also carried out using Statistical Package for the Social Sciences (Version 21) (SPSS Inc, Chicago).

Implications of the study

1. The test battery developed and standardized provides normative data on tasks used to assess phonological representations in typically developing native speakers of Kannada in the age range of 3-5 years.
2. The test battery helps to assess phonological representations in children with developmental disorders (Speech Sound Disorder, Specific Language Impairment, Childhood Apraxia of Speech and at risk for Dyslexia).
3. The tasks in the test battery will serve as useful clinical tools to be used in speech therapy for children with poor phonological representations.

REVIEW OF LITERATURE

Phonology refers to the sound structure of various elements within individual language whereas phonetics refers to the properties of a sound in general, their production, transmission and perception. The minimum contrastive unit of sound in a given language is called phoneme. The study of phonology helps distinguish each sound in a language. Phonology includes both segmental and non-segmental aspects. The role of phonology in the development of oral and written language has been well established (Fowler & Liberman, 1995; Scarborough, 1998; Wagner & Torgesen, 1987). Linguistic information is coded in the brain as abstract mental representations of the components of language, including phonology, semantics and syntax. At the level of phonology, these representations consist of codes for the individual phonemes of a language and rules for their systematic organization, which appear to develop gradually (Wolf, Vellutino, & Gleason, 1998).

'Representation' reflects on how information is maintained in a system (Hester & Hodson, 2004). The neural correlates of representations in the brain are seen as cortical patterns of synaptic connectivity (Elman et al., 1996). ‘Phonological representation’ refers to the mental representation of individual sounds and sound sequences that form meaningful words in the respective spoken language. Locke (1988) described phonological representation as the underlying sound structure of particular words in long-term memory. It is also defined as the cognitive description of the distinguishing phonological patterns of a language (Nag-Arulmani et al., 2003). Phonological representations are the repository for information about speech sounds considered as the building blocks of speech. They are either holistic (i.e., words are considered as the smallest single unit) or segmental (i.e., words considered to comprise subunits that can be deliberately manipulated). The earliest linguistic representations in a developing child are reported to be typically holistic or gestalt-like (Fowler, 1991; Studdert-Kennedy, 1987; Treiman & Zukowski, 1991). Segmental phonological representations enable processing of phonological information at the level of syllable, onset-rime or phoneme and are said to emerge during the initial years of speech and language development in a typically developing child (Fowler, 1991). Retrieval of phonological representations from long term memory to the working memory is essential for decoding of language (Baddeley, Lewis, & Vallar, 1984). This phenomenon occurs in congregation with speaking tasks (Levelt, 1989), and also in reading tasks (Brady, 1991).

Fowler (1991) has proposed that there are individual differences in the accuracy of underlying sound structures of words and their organization in the mental lexicon. Words with poorly specified representations lack detailed organization into its constituent elements and hence, an accurate phonetic code is not available. This will hinder accurate manipulations of the phonetic form of the word at the segmental level. Other researchers have also suggested that accuracy of the phonological representations of words plays an important role in phonological awareness tasks compared to the understanding of phonological segments of words (Hulme & Snowling, 1992; McDougall, Hulme, Monk, & Ellis, 1994; Snowling & Hulme, 1989). These investigators hypothesized that subjects may have difficulty in performing segmental operations on phonological representations if their output representations are not well specified or sufficiently accurate.

Conceptually, phonological representation of a word contains detailed phonemic and phonetic level information. An immature phonological representation in a young child is characterized by general acoustic information and phonetic features that would suffice discrimination among the small set of words in their vocabulary (Menyuk & Menn, 1979; Walley, 1993; Waterson, 1971). On the other hand, well-developed phonological representations of older children with large vocabularies are believed to include other perceptual information about a word. The additional information could be auditory (e.g., sounds of the phonemes) and/or visual (e.g., articulatory movements) information about a word that facilitates accurate perception and differentiation from similar words in the lexicon (Stackhouse & Wells, 1997). The perceptual information in the input signal is then compared and matched with information contained in the phonological representation, which in turn facilitate access to the parallel semantic and orthographic representations (Stackhouse & Wells, 1997). This interaction takes place during decoding of spoken language as well as printed text.

Pierrehumbert (1990) deliberated on the disparate view on the relationship between phonological and phonetic representations. The output of phonology is considered as the input to a phonetic component which is then mapped onto a phonetic representation. Phonological representations are considered qualitative whereas phonetic representations are quantitative. However, there is no consensus in the literature with reference to the use of the term phonological representation. Some use it to refer to representation-related phonological processing ability (Anthony et al., 2010), while others define it precisely to refer to the underlying organization (Hester

& Hodson, 2004). *In this study, the term "phonological representation" is used to refer to the specific nature of phonological processing*.

Based on the review of literature, Anthony et al. (2010) postulated four distinct types of phonological processing abilities based on aspects of phonological representation: (a) ability to form new phonological representations, (b) ease of access to the existing phonological representations, (c) accuracy of receptive phonological representations, and (d) accuracy of expressive phonological representations. Individuals are reported to differ with respect to coding and accessibility of the phonological information of words (Anthony et al., 2010; Anthony et al., 2011).

A range of phonological processing skills are implicated in the development of oral and written language. For example, speech perception, phonological awareness, articulation, phonological memory span and others. A common aspect amongst these phonological processing abilities is that of access to phonological representations of words (Anthony et al., 2010). The National Early Literacy Panel (2008) reported that skills such as phonological awareness, phonological short-term memory, and efficiency of access to phonological representations were among the unique predictors of literacy outcomes. Few investigators (Elbro & Pallesen, 2002; Elbro et al., 1998; McBride-Chang, 1995; Roberts, 2005) suggest that understanding the nature of phonological representations is essential to: (a) establish individuals' proficiencies in spoken and written communication (b) acquire literacy (c) understand indirectly the acquisition of reading through the development of phonological awareness and (d) understand the direct influence in decoding text and indirect influence in the development of phonological awareness.

Researchers have investigated the relationship between stored phonological representations and the ability to perform on phonological representation tasks. Accurate, distinct and segmented underlying representations of words in long-term memory are linked to the development of phonological awareness (i.e. awareness of the sounds within words) and learning the alphabetic principle (Elbro, 1998). In this regard, phonological awareness tasks are considered as a ‘window into the lexicon’, as it provides an opportunity to understand the nature and accuracy of phonological representations (Claessen et al., 2009).

Phonological representation plays a significant role in building the relationship between phonology, phonological awareness, and eventually in literacy skills. Poorly specified or incomplete underlying phonological representations of words result in difficulty to use phonological information in reading and spelling (Fowler, 1991; Metsala, 1997a; Mody, 2003; Sutherland & Gillon, 2005; Swan & Goswami, 1997). ‘Poor’ readers lack complete awareness of the phonetic aspects of a sound, and grapple with identification and discrimination of phonemes. In contrast, ‘good’ readers utilize their phonological awareness skills to access fully developed representations consisting of finer articulatory details and thus, are able to produce words accurately.

Theoretical Perspectives

The linguistic perspective has significantly influenced the understanding of phonology. Over the last five decades, several theoretical frameworks were proposed to explain various aspects of phonology and phonological processing. These in turn have influenced the clinical approaches with regard to assessment and intervention strategies used to address the disordered phonology.

Most of the theoretical perspectives in phonology focus on the linguistic basis to understand the organization of sounds in the brain. Until 1950s, the focus of research in the area of phonology was on the surface forms i.e. analysis of speech of an individual to understand the various aspects of phonology. Gradually, the focus shifted to those features considered as abstract representations stored in the brain; which could be acoustic (voice, continuant), articulatory (high, lateral etc) or function based (vocalic or consonantal) mostly binary in nature. However, as research in the area began to expand, investigators began to realize the limitations of feature analysis, specifically its inadequacy in addressing the linguistic organization in brain. As an attempt to address this gap, the structuralist theories emerged with the focus on phoneme, attempting to understand the contrastive properties and surface phonetic forms. This was followed by theories in the area of Generative Phonology.

According to Generative Phonology, phonological representations are considered as sequences of segments consisting of distinctive features. Distinctive features are drawn from a universally fixed set and are binary in nature indicating either the presence or absence of a particular articulatory or perceptual characteristic. It recognizes two levels of representation namely the surface phonetic representation and the underlying representation governed by ordered phonological rules. Emphasis is on the segments rather than the syllable. The theory of distinctive features proposed by Jakobson, Fant, and Halle (1952) was modified by Chomsky and Halle (1968) who put forth the theory of Sound pattern of English (SPE). SPE proposes that the distinctive features underlying an utterance and its representations are arranged in the form of matrices in which each column corresponds to one segment. Universal grammar is believed to be mediated by a set of forms and functions of phonological rules. In this perspective, an utterance is considered as an ordered sequence of segments, which includes all the segmental and prosodic properties, interceded by distinctive features and phonological rules. Despite this extensive view, it fails to explain all aspects of phonological representation.

Theories proposed in line with Generative phonology explained both the surface forms as well as the underlying representations using a set of rules. Several theories with different rule ordering were put forth during this period to explain the relationship between surface phonetic and underlying phonological representations. Amongst these, the autosegmental and metrical phonology were prominent.

Autosegmental Phonology: The classical theory of Generative Phonology mainly described the segmental phenomenon and assumed a one-to-one relation between the specifications of any given distinctive feature and the corresponding segment. Therefore, phonological representations were described in the form of a simple matrix with distinctive features represented by rows and successive segments by columns. However, this did not hold good for tonal phenomenon as it was seen that a single distinctive feature could relate to either one or more segment. Thus, Goldsmith (1976), proposed the autosegmental theory which explains that the phonological representations operate on separate tiers of linear sequences of segments that are connected by association lines. In this theory, distinctive features are considered to be autonomous in nature without any uniform relationships among them. These developments led to the concept of nonlinear phonology, first introduced by Goldsmith (1979).

Metrical Phonology: Stress was considered as a phonological feature in SPE and a value was assigned to the stressed segment in the representation of a word, thereby attributing several properties to the feature [Stress] that was not correlated to other features. Stress was considered as a relational aspect of arranging syllables into larger structures rather than as a segmental feature. Metrical phonology allows for conceptualization of segments into syllables which in turn are organized into larger units called feet followed by phonological words, phrases etc. The study of these units and their internal organization along with their relationship to one another further strengthens the understanding of phonological representations.

Feature Geometry: This is an extension of autosegmental phonology, where feature geometry represents distinctive features in a structured hierarchy. The basic premise of feature geometry is that certain sets of distinctive features can be grouped together based on a common pattern. Thus, feature geometry represents a common set of features under a shared parent node in a tree.

Optimality Theory: This theory was initially put forth by Prince and Smolensky (1993) and it highlights a universal set of constraints rather than rules. It proposes that the observed forms of language are products of interaction between conflicting constraints. The grammar system is assumed to have three universal components, namely the input, constraint and output. The input refers to the underlying representations and the output refers to the surface forms. Thus, whenever there is an input, a set of options are made available and the output is chosen based on the rank order of constraints on the surface forms.

Subsequent to the theories on Generative phonology, assumptions that phonology was based on a universal set of phonological processes called ‘Natural Phonology’ emerged (Stampe, 1979). This approach explained that activation and suppression of phonological processes are language specific and they are concerned with the distinctive features within prosodic groups rather than segments. It assumed that the underlying representations in children are similar to that of the adult and that children only simplify their productions in the early stages (phonological processes), and the extent of simplification reduces with age as speech approximates the adult form.

Linguistic approaches described the phonological representations fairly well by offering detailed descriptions of the phonological systems in children. However, they failed to explain the mechanism of functioning of either a normally developing system or an impaired system. Thus, linguistic approaches viewed only a single perspective in understanding speech difficulties in children (Stackhouse &Wells, 1997). This lacuna was overcome to some extent by the medical perspective which aims to identify and explain the underlying cause of speech difficulties. This holds good in cases of organic pathologies leading to speech impairments that could be medically intervened. Hence, the linguistic and medical approaches complement each other with the former describing the language system in children while the latter considers the neuroanatomic base of speech and language (Baker, Croot, McLeod, & Paul, 2001). However, both the approaches do not sufficiently explain speech impairments where a definite causative factor cannot be identified, which is the case more often than not, in a clinical situation. These factors led to the development of psycholinguistic approaches to explain the development of speech and language and the levels of breakdown in an impaired system.

Psycholinguistic approaches explain the processing of normal speech and language at the cognitive level and hence, any impairment in speech and language is considered as a breakdown in one or more components of the psychological processing involved. It provides a framework to explain impaired phonological systems based on information derived from linguistic assessments (Stackhouse & Wells, 1993). The primary components of a psycholinguistic model of speech production are the processes concerned with "perception, storage, planning and production of speech as it is produced in real time in real utterances" (McCormack, 1997). A simple psycholinguistic model attempts to explain three components of speech processing namely the reception of words, their underlying representations and their production (Dodd, 1995; Fee, 1995). Psycholinguistic approaches allow for comprehensive investigations, description and profiling of a child's speech and literacy problems through the application of developmental models. They also permit examination of the processing mechanisms involved in assessment tasks and identification of areas of strength which in turn facilitates specific intervention strategies (Baker et al., 2001). The psycholinguistic models take into account both processing demands in assessment procedures and the developmental considerations. Although the assumptions of various psycholinguistic theories and models of speech processing vary, each of them testify the significance of phonological representations in acquiring new words and its contribution to the development of literacy (see Baker et al., 2001 for a thorough review).

Psycholinguistic models of speech perception and production assume various forms. While few models support the notion of unified phonological representations for speech perception skills like judgment tasks and speech production abilities like naming (Fikkert, 2007; Griffiths & Snowling, 2001), others posit separate but related phonological representations for the two functions (for example Claesson & Leitao, 2012; Monsell, 1987; Stackhouse & Wells, 1997). In the unified approach, the phonological representations for speech perception and speech production are assumed to be stored together and recruited from the same store (Casserly & Pisoni, 2010; Galantucci, Fowler, & Turvey, 2006). This notion of a unified phonological representation across perception and production is also supported by neurobiological studies (Fadiga, Craighero, Buccino, & Rizzolatti, 2002; Rizzolatti et al., 1996). Poorly specified phonological representations result in deficient mapping between orthographic and phonological representations leading to difficulties in literacy acquisition.

The earliest psycholinguistic models (e.g.: Menn, 1978; Smith, 1973) were considered as ‘box-and-arrow models’ where a “box” represented the hypothetical level of representation or processing and the “arrows” represented the relationship between the processes or additional processes. Box-and-arrow models were used to explain either a simple relationship between the input and output signals (e.g., Menn, 1978; Smith, 1973) or complex relationships involving multiple levels of processing (e.g., Hewlett, 1990; Hewlett, Gibbon, & Cohen-McKenzie, 1998; Stackhouse & Wells, 1997). Application of phonological rules on the underlying representations was implicated based on the differences observed between perception and production abilities in children.

Smith (1973) proposed a single lexicon model of phonological representations which states that the underlying representations of speech are stored in one lexicon. Children's underlying representations are perceptually based and considered adult-like, similar to surface representations of adults. When phonological rules act on the stored underlying forms, they are modified into surface representations and application of articulatory instructions resulting in speech output. The major drawback of this model is its inability to explain the inconsistencies seen in production despite the assumption that child's perception is adult-like. Hence the model was revised in 1978 to account for the inaccurate perception by including perceptual filters. However, they failed to account for the phenomenon of variable pronunciations, particularly when different tokens of a given word were produced in different ways by the same child or when the same phoneme was produced differently in different words (Bernhardt & Stemberger, 1998). Thus, there arose a need to explain variability in the speech of children. Further, it was proposed that the underlying representations correspond to the respective language system in both typically developing children in the initial developmental stages and children with speech impairment. These factors resulted in the development of two-lexicon models (Hewlett, 1990; Kiparsky & Menn, 1977; Menn, 1983; Spencer, 1988) consisting of an input lexicon and an output lexicon. The perceptual based, adult-like underlying representations are stored in the input lexicon and are modified offline by phonological rules resulting in the formation of new representations stored in the output lexicon for subsequent productions (Menn, 1978). However, this does not rule out the possibility of replication of entries in the output lexicon, thereby failing to explain the process of choosing one representation over another, changes involved in achieving more adult-like representations and the deletion of old representations

(Bernhardt & Stemberger, 1998; Dinnsen, Barlow, & Morrisette, 1997; Vihman, 1996). This was further modified by Hewlett (1990), in which the underlying representations are related to the articulatory-phonetic production through a motor programmer. The provision for feedback and interaction among the components of the model enables modifications of entries in the output lexicon to more adult-like representations.

One of the box-and-arrow psycholinguistic models of speech processing was put forth by Stackhouse and Wells (1997). This theoretically driven model has found wide clinical applications in assessment and intervention of children with speech and literacy difficulties (Snowling & Stackhouse, 1996; Stackhouse, 1992, 1993, 1997; Waters, Hawkes, & Burnett, 1998). This model includes three components namely the speech processing profile, the model of speech processing and the developmental phase model. In this model, the existence of a single underlying representation, referred as the lexical representation is hypothesized to include phonological, semantic, syntactic, orthographic and motoric representations (Stackhouse & Wells, 1997). The lexical representation is linked to a large number of processes beginning from the peripheral auditory processing in the input to the motor execution in the output. Over the years, box-and-arrow models have made way for the development of computer based connectionist models. While box-and-arrow models systematically explain the steps involved in cognitive processing using verbal reasoning, connectionist models are generally described as neural networks.

Overall, theoretical accounts proposed to explain the development of phonology can be mainly grouped under two headings - the modular view/accessibility position and the holistic view/emergent position. The modular view is based on the assumptions of conventional theories of speech perception and processing where phoneme is considered as the basic unit of representation. According to the modular view, lexical representations are implicit. Proponents of the modular view suggest that phonemic structures of words are stored within the lexical representations of children from birth in a highly modularized manner (Liberman, 1970). However, children are unaware of these structures initially and they are made explicit with the acquisition of literacy skills i.e. when children are taught to read. In contrast, the holistic view advocates that the initial representations are holistic and are gradually refined during the early years of development with the addition of phonological information. The process of refinement of the lexical representation is prompted by the increase in vocabulary in order to facilitate differentiation of items that are phonologically similar (e.g., Metsala & Walley, 1998). Therefore, vocabulary growth is considered as an impetus to the emergence of phonological awareness which is a vital prerequisite for the enhancement of reading skills. The refinement of children's phonological representations is proposed to continue until the age of 7 years (Fowler, 1991; Nittrouer, Studdert-Kennedy, & McGowan, 1989).

One of the widely acknowledged theories encompassing the emergent view is the Lexical Restructuring Hypothesis (Metsala & Walley, 1998). The assumptions of The Lexical Restructuring Model (Walley et al., 2003) are four fold: (a) the representations of the entities in the mental lexicon of young children are holistic in nature and are assumed to gradually become segmented during the developmental years (b) the segmentation process of early lexical representations occurs over time commencing from early infancy to middle childhood as it is largely depended on vocabulary growth (c) the lexical restructuring serves as a precursor to development of phonological awareness abilities and hence, a delay in restructuring may contribute to reading disabilities and (d) development of reading abilities is not a precursor to phoneme awareness but serves to compliment as well as maintain phoneme awareness skills.

Spoken vocabulary growth and the rate of vocabulary expansion are postulated as the key elements in the process of segmentation of phonological representations (Metsala & Walley, 1998; Locke, 1988). Metsala and Walley (1998) propose that the extent of segmental representation determines the growth of phonological awareness skills which in turn determines literacy achievements. During the preschool years, a spurt in the vocabulary increases the size of the lexicon, thereby inducing greater demands for restructuring words into finer units like syllables, onsets and rimes. This process of lexical restructuring also depends on word frequency and neighbourhood density in the lexicon. High frequency words or words acquired early are generally restructured initially as these words are very often required to be accessed accurately and rapidly. Similarly, the presence of a large number of similar-sounding words or a dense neighbourhood in the lexicon would necessitate restructuring owing to the need to distinguish between such words. On the other hand, low frequency words and words in ‘sparse’ neighbourhoods are restructured later on as such words are only used sparingly and need to be distinguished from a small number of similar sounding words. Walley et al. (2003) hypothesized an influence of both “global” and “local” features of vocabulary expansion on the development of lexical representations. Global aspects refer to variations in the rate of increase in vocabulary whereas local aspects refer to variations in the frequency of words and the dynamic neighbourhood effects during the course of development. Further, sonority profile of the language is also known to exert an influence on the development of phonological representations (Goswami, 2010). Sonority profile refers to the category of sounds that make up a word. In general, vowels are considered the most sonorant sound class followed by glides, liquids and plosives in that order.

The assumptions of the lexical restructuring hypothesis were questioned for many reasons in the recent years. First, evidence of dense phonological neighbourhoods in young children than what was conceptualized initially necessitated early lexical restructuring (e.g., Coady & Aslin, 2003; Storkel, 2004). However, the process of segmentation was postulated to be gradual and progressive (Bowey & Hirakis, 2006). Further, it was reported that segmentation based on phoneme similarity is evidenced only for words in dense neighbourhoods whereas those in sparse neighbourhood continue to be holistically represented based on similarities in manner of production. Ability to detect mispronunciation in children around the age of two years was studied using habituation-switch tasks (Fennell & Werker, 2003; Werker et al., 2002) or preferential looking tasks (Bailey & Plunkett, 2002; Ballem & Plunkett, 2005; Swingley & Aslin, 2000, 2002), in order to understand phonological representations in young children. Most of these studies however, involved participants with mispronunciation of word-initial consonants. Earlier research has shown that the initial segments of words are perceptually prominent even in prelinguistic children (Jusczyk, Goodman, & Baumann, 1999). Hence, detection of mispronunciation of word initial consonants cannot be construed as indicative of lexical restructuring (Bowey & Hirakis, 2006). Researchers have also shown that older children also face difficulties in discriminating between words that are minimally different, thereby suggesting that the lexical restructuring could continue beyond the age of two years (Barton, 1976, 1980; Eilers & Oller, 1976; Gerken, Murphy, & Aslin, 1995; Metsala, 1999; Stager & Werker, 1997). Ventura, Kolinsky, Fernandes, Querido, & Morais (2007) compared literate and illiterate adults on gating tasks and speech identification in noise and reported that segmentation of lexical representations is evidenced even in the absence of literacy skills. However, the development of conscious phoneme awareness was still largely dependent on acquisition of alphabetic literacy.

The 'Psycholinguistic Grain Size Theory' (Zeigler & Goswami, 2005) was put forth as another modification of the emergent view. According to this theory, children are initially sensitive to larger phonological units in speech and this sensitivity is gradually refined to make a distinction between smaller units. This theory contends that phonemic awareness does not automatically develop with increase in age. Awareness for larger phonological units of words like syllables, onsets and rhymes develops as a consequence of expansion of vocabulary. However, direct instruction at the level of phoneme (e.g., Byrne & Fielding-Barnsley, 1995; Morais, Content, Bertelson, Cary, & Kolinsky, 1988) or exposure to literacy, particularly in alphabetic scripts (Liberman, Shankweiler, Fischer, & Carter, 1974) is a requisite for the development of awareness of smaller phonological units. Hence, this theory is similar to the lexical restructuring hypothesis in that vocabulary growth is considered a precursor to the process of segmentation. However, the two theories differ in their positions with regard to the role of literacy in the process of restructuring. While lexical restructuring hypothesis proposes that phonemic representations drive phonemic awareness, the psycholinguistic grain size theory stands in contrary to this by proposing that phonemic representation is the result of learning to read. The conflicting views of these two accounts led to the development of another model referred to as PRIMIR (Processing Rich Information from Multidimensional Interactive Representations) by Werker and Curtin (2005). PRIMIR is a model based on a developmental framework that includes components of the accessibility view as well as the emergent view. PRIMIR consists of multidimensional interactive representational planes and dynamic filters that aim to explain the nuances of infant speech processing and language development and also the relationship between them. PRIMIR addresses two primary concerns in infant speech perception namely a) Speech perception is both categorical and gradient b) Ontogenetic development and online processing influences speech perception.

PRIMIR assumes that a child picks up the rich information contained in the speech input and organizes the same along several planes that are multidimensional and interactive in nature (General Perceptual plane, Word Form plane, and Phoneme plane). The information along these planes is simultaneously processed by three dynamic filters related to the initial biases, the developmental level of the child, and the particular task demand faced by the child, which results in either enhancement or reduction in the physical properties of the signal (acoustic, phonetic, gestural, visual, etc.). Availability and access to information varies at various stages of development and the use and choice of information for various linguistic tasks is guided by the planes. The General Perceptual plane plays a role in discrimination tasks that require language specific categorical, phonetic and indexical information. These attributes facilitate segmentation in the Word Form plane that accounts for speed and accuracy in perceptual tasks. The Phoneme plane contributes to identification tasks that rely on the phonemic system of the language. The dynamic filters ascertain that the various phoneme combinations learnt by the child adhere to the linguistic constraints. The initial biases in infants render certain features of the perceptually available rich information more relevant that is selectively processed. The perceptual salience is different for different linguistic tasks and this task specificity varies across the developmental stages of the infant. Thus, processing and representations are inextricably intertwined in PRIMIR in which information is represented both categorically and as gradient along multidimensional planes and the influence of age and task are reflected in the performance through the action of dynamic filters.

A study by Ainsworth et al. (2016) supported the claims made by lexical restructuring model and PRIMIR. Novel measures of phonological representations that are specifically devised to measure accuracy and segmentation of phonological representations were administered on preschool children aged 3;6 to 4;6 years who were not introduced to formal reading. The results suggested that children's phonological representations gradually become accurate and segmented with development, thereby supporting the emergent view. They also reported that restructuring of phonological representations was primarily driven by vocabulary growth although minimal literacy experiences in the preschool children partly facilitated the process.

Earlier, investigators have developed assessment and intervention protocols for children with impaired language systems from a psycholinguistic perspective (Chiat, 2000; Stackhouse & Wells, 1997). Applications of psycholinguistic models to understand developing language system of children necessitates clear understanding of task demands and developmental levels of children (Roy & Chiat, 2008). The processing demands involved in each task should be clearly understood to facilitate accurate interpretation of performance on the respective task. Administration of such tasks in children with typical language development would aid in-depth understanding of the developmental patterns and processing involved. This in turn, would help understand the processing deficits or developmental lag, if any, in children with delayed or deviant language development.

Development of Phonological Representations

Within the vast extant of research reported on the development of phonological awareness in both typical children and those with speech and language impairments, few studies (e.g., Carroll & Snowling, 2004) have highlighted the significance of phonological representations in the development of phonological awareness and in turn, the emergence of literacy skills.

The role of phonological representations is significant in the development of fluent speech as well as literacy skills in children in later stages. It is thus essential to understand the nature and development of phonological representations along with the factors influencing their development. Categorical perception implies that the brain imposes sound catgeories onto a physical continuum. Categorical perception of phonemes is evidenced in infants as young as 1-4 months (Eimas, Siqueland, Jusczyk, & Vigorito, 1971) suggesting that sensitivity to phonetic boundaries are present from birth. The phonetic boundaries are language specific and influenced by auditory perceptual abilities (Kuhl, 2004). Athough categorical perception is evidenced at birth, they are gradually refined during the developmental period. Similarly, phontactics or the rules governing the phoneme sequences to form words in particular langauges determine the word boundaries in continuous speech. This ability is reported to develop at around 7 months of age (Jusczyk & Aslin, 1995). In addition to phonotactics, motherese and prosodic information such as stress and duration are also considered as important aspects of phonological representations for words (Jusczyk, Houston, & Newsome, 1999). The increased sensitivity of infants to prosodic and rhythmic patterns in language is reported for both perception and production (de Boysson-Bardies, Sagart, & Durand, 1984).

There are conflicting opinions expressed on the nature of segmentation of the phonological representations during the developmental period. Proponents of the lexical restructuring hypothesis suggest that the lexical/phonological representations undergo segmentation gradually beginning from early years of speech and language development (Fikkert, 2010; Garlock, Walley, & Metsala, 2001; Storkel, 2002; Walley et al., 2003). The initial holistic representations are considered adequate for differentiating the words in the lexicon of young children which are phonemically distinct from each other (e.g., Charles-Luce & Luce, 1995, Logan, 1992). As the vocabulary develops, the representations of spoken words become more fine-grained in order to help children to differentiate between words with significant phonemic overlap. The restructuring of phonological representations during the developmental period were examined using several experimental paradigms. Walley and Flege (1999) supported the claim that young children have holistic representations by comparing identification abilities of five- and nine-year-old children on vowel continuum in native and foreign language. Although no significant age effect was observed for phoneme boundaries, progressively steeper slopes of identification functions were found with increase in age, particularly for the native continuum.

Metsala (1997b) used the gating paradigm where increasing longer segments of a spoken word were gradually presented to children aged 7, 9 and 11 years and adults for identification. Results revealed significant interaction effects for word frequency and neighbourhood density. High frequency words from dense neighbourhood showed lesser developmental differences while low frequency words with sparse neighbourhood showed greater differences across age groups. These findings were explained based on lexical restructuring as frequently occurring words in the lexicon are expected to undergo segmental restructuring prior to sparingly occurring words which are more holistically represented. A study by Garlock et al. (2001) revealed similar findings in preschool children, beginning readers and adults based on gating and word repetition tasks.

Studies have reported a positive correlation between the refinement of phonological representations and increase in receptive vocabulary (Befi-Lopes et al., 2010; Gray, 2004; Jusczyk, 1993; Kuhl, 1993, Maillart, Schelstraete, & Hupet, 2004; Metsala & Walley, 1998), emergent literacy skills (Sutherland & Gillon, 2007), feedback between representations of information in the domains of acoustics and articulation representations and verbal imitation (Plaut & Kello, 1999). According to Befi-Lopes et al. (2010), phonological representations are fundamental to phonological awareness, oral language and writing abilities and hence enable target specification in the therapeutic process.

The quality of phonological representations in the lexicon has been postulated to be an essential prerequisite for phonemic awareness (Elbro et al., 1994; Fowler, 1991). Elbro (1996) hypothesized that typically developing children have difficulty in pronouncing and consciously manipulating words whose phonological representations are of poor quality or less "distinct" whereas children with reading difficulties have limited access to the most distinct forms of phonological representations. "Distinctness" was defined by Elbro (1996) as the "degrees of difference or separateness of a word's phonological representation from similar words and the amount of phonological information that is stored with the word". A lexical representation was considered distinct when there are sufficient features that serve to discriminate it from other entries in the lexicon. Elbro (1996) suggested that less distinct phonological representation of a word renders tasks that require conscious operation on the word's segmental components difficult. Additionally, phoneme grapheme correspondence skills in a child may directly rely on the distinctness of the lexical representations. This hypothesis is supported by a longitudinal study in Danish language (Elbro et al., 1998). Elbro et al. (1998) used an articulation correction task in which a child was asked to identify and correct mispronunciations of complex words produced by a puppet (the investigator served as a ventriloquist). Three separate tasks namely, letter naming, phoneme identification, and distinctness of phonological representations were independently identified as predictors of dyslexia in kindergarten children. However, the independent contributions of receptive and expressive vocabulary to the prediction of phonological awareness skills in second grade were not significant. In this regard, individuals with inaccurate phonological representations were predicted to experience errors in articulation. The investigators concluded that ready access to precise phonological representations is one of the prerequisites for fluent oral language abilities. Unlike the lexical restructuring hypothesis, the highest level of distinction in the distinctness theory need not always be at the level of phoneme but could incorporate allophones.

Phonological representations of words are sufficiently developed by the age of 3 to 4 years to facilitate accurate comprehension and production of the component phonemes along with correct intonation patterns. The ability of children to reflect on the internal sequences of phonemes in words develops with the development of phonological representations. Phonological awareness skills such as rhyming and counting the number of syllables in words develop around 4 years of age while phonemic awareness is reported to develop at around 6 years of age when children are exposed to alphabetic scripts (Goswami, 2012). Bishop and Snowling (2004) suggest that distinct phonological representations are developed consequent to literacy acquisition.

The stored representations of words are known to include information in the domains of semantics, grammatical orthography and phonology. The process of fast mapping or a brief exposure to sounds in words facilitates phonological representations (Fisher, Hunt, Chambers, & Church, 2001). The nature of orthographic system is also reported to have an effect on the maturation of the phonological representations (e.g., Gupta, 2004; Karanth, 2002) although the interaction between the two domains is not clearly delineated. Naming speed, orthographic and phonological knowledge at both syllable and phoneme levels were reported as predictive of individual variations in reading profiles of Kannada readers in the age range of 9-12 years (Nag & Snowling, 2012).

Studies on phonological acquisition report that phonological representations develop throughout childhood (e.g., Edwards, Beckman, & Munson, 2004; Hazan & Barrett, 2000; Treiman & Zukowski, 1996), and the emergence of abstract phonological representations in childhood is tied to developmental changes in vocabulary size (Edwards et al., 2004).

Claessen et al. (2009) used a task called Quality of Phonological Representation (QPR) and a lexical decision task to study phonological representations in preprimary children (average age range = 5;5 years) in the absence of a verbal response. The children were instructed to judge correct or incorrect productions (pseudo-words) of multi-syllabic words presented auditorily along with pictures displayed on the computer screen. The latency and accuracy of the responses were analyzed. The results of this study indicated that the QPR was a useful screening tool for the assessment of phonological representations in preprimary children. Qualitative analysis of the data also revealed that errors were most likely to occur when place of articulation of nasal consonants, voicing and height of vowels varied. Follow up study of the same group of children two years later (average age = 7;9 years) revealed higher accuracy and reduced latency of responses thereby indicating an increase in the ability to judge correct and incorrect productions of multisyllabic words.

Developmental changes in phonological representations in children were also investigated using a modified phonetic imitation paradigm in association with picture naming task (Nielson, 2013). Voice Onset Time (VOT) was measured in preschool and third grade children before and after exposure to target speech with synthetically lengthened VOT. Results revealed that both groups of children were able to imitate the extended VOT with the degree of imitation being greater in younger group. Generalization of extended VOT was also observed in the imitation of novel words indicating both phoneme and feature representations in the two groups of participants.

However, word specificity was found to be stronger in older children and this was attributed to the well developed lexicon in this group, thereby supporting the notion of a developmental trend of phonological representations.

The contribution of speech perception in the acquisition of phonology has gained increased attention in the last few decades (e.g. Broe & Pierrehumbert, 2000; Hume & Johnson, 2001). This can be mainly attributed to two aspects – relation of markedness concept to phonetic grounding in both perception and production studies (Davis, McNeilage, & Matyear, 2002; Hayes, Kirchner, & Steriade, 2004) and the specificity of phonological representations that provides a link between perception and production.

Naming speed is considered as a part of phonological skills (Torgesen, Wagner, Rasholte, Burgen, & Hecht, 1997) and hence, Rapid Automatized Naming (RAN) tasks are frequently included in the test batteries of phonological abilities. RAN assesses the ability to name serially presented familiar visual stimuli as rapidly as possible. The concept of RAN originated with the study by Geshwind and Fusillo (1966) where they observed color naming difficulties in individuals with stroke. Later, Denckla (1972) observed color naming difficulty in five boys (aged 7.5-10.7 years) with reading failure and reported that naming speed rather than accuracy helped to differentiate poor readers from others. In a later study, Denckla and Rudel (1974) included digits, letters and common objects as stimuli for RAN in addition to colors thereby making these four categories as the most commonly used stimuli for RAN task. However, different stimuli have been used to study rapid naming abilities in the recent times. A study by Biddappa, Seth and Manjula (2016) investigated rapid naming abilities with nouns and verbs as stimuli and reported significant differences in the performance of children on the two classes of words. Developmental trends in rapid naming abilities are reported by many investigators (Anthony et al., 2010; Araujo, Ferreira, & Ciasca, 2016; Cohen, Morgan, Vaughn, Riccio, & Hall, 1999; Khurana, 2011; Kuppuraj & Shanbal, 2009; Ranjini & Rajasudhakar, 2011).

Most popularly, RAN is reported to be predictive of later reading achievement (Allor, 2002; Cutting & Denckla, 2001; Wolf & Bowers, 1999) independent of phonological awareness, verbal intelligence and existing reading abilities (Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007; Wolf, Bowers, & Biddle, 2000). Norton and Wolf (2012) suggested that RAN constitutes "a microcosm or mini-circuit of the later-developing reading circuitry". Different theories have been postulated to resolve the RAN-reading relationship. The recent view put forth by Shaywitz (2003) explained rapid naming as an index of phonological access.

Wolf (1997) considered RAN and phonological processing as markers for different cognitive processes, supporting this view with the proposal of double deficit theory of reading disability which suggests that the two variables represent independent cognitive functions. According to this theory, those with reading disability are found to have deficit in both these domains (Bowers, 1996, 2001; Wolf, 2001; Wolf & Bowers, 1999). In contrast to double deficit theory, other investigators reported RAN as a phonological process which governs the reading speed (Bowers & Wolf, 1993; Catts, Gillispie, Leonard, Kail, & Miller, 2002; Wagner, Torgesen, & Rashotte, 1999). Reading accuracy (Torgesen, 1999) and speed (Wolf & Bowers, 1999) are reported to be primarily supported by phonemic awareness and RAN.

RAN tasks have also been extensively studied in children with a variety of developmental disorders. Several researchers have reported impaired RAN abilities in children with reading disability (Araujo et al., 2011; Kirby, Parrila, & Pfeiffer, 2003; Vaessen et al., 2010; Wolf et al., 2000; Wolf et al., 2002). Wiig, Semel, and Nystrom (1982) reported poor performance of children with primary language disorders compared to age matched typical children on rapid naming tasks. Similar findings were observed in children with specific language impairment (Lahey & Edwards, 1996; Miloshevic & Wukovic, 2017) and high functioning individuals with autism (Losh, Esserman, & Piven, 2010). Zaretsky, Velleman, and Curro (2010) reported below average performance on accuracy and automaticity of information retrieval on RAN and Rapid alternating stimuli in a 6 year old child with Childhood Apraxia of Speech.

RAN tasks facilitate understanding of underlying representations of words. Claessen, Leitao, Kane, and Williams (2013) showed that RAN is a useful measure to assess how fast the phonological codes can be retrieved from the lexicon. Deficits in RAN tasks reflect inaccurate underlying phonological representations, which in turn are believed to hinder their accessibility (Bowey, McGuigan, & Ruschena, 2005; Heikkila, 2015; Kibby, Lee, & Dyer, 2014; Pennington, Cardoso-Martins, Green, & Lefly, 2001; Ramus, 2014; Ramus & Szenkovits, 2008; Savage, Pillay, & Melidona, 2007; Torgesen et al., 1997; Vaessen, Gerretsen, & Blomert, 2009; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Wagner et al., 1997). Difficulties in RAN were also reported as a result of poor motoric level and/or slow processing abilities (Miller, Kail, Leonard, & Tomblin, 2001).

Performance on phonological processing abilities is reported to be influenced by gender with girls generally outperforming boys in a wide variety of tasks, especially verbal (Deaux, 1985; Halpern, 2013; Hyde & Linn, 1988; Maccoby & Jacklin, 1974; Moura, Mezzommo, & Cielo, 2009). Differences in the quality of phonological representations is purported to be the reason for differences between the two genders in processing pre-lexical and lexical information (Majeres, 1999, 2007; McGuiness, 1981). Gender differences are also reported in speech production abilities where girls were found to have more accurate and consistent articulation (Dodd, Holm, Hua, & Crosbie, 2003; Kenny & Prather, 1986; McCormack & Knighton, 1996). It was also observed that there are differences in hemispheric specialization for processing phonological information between males and females. While there was evidence for bilateral activation in females, activation patterns were limited to the left hemisphere in males (Pugh et al., 1997; Shaywitz et al., 1995). However, other investigators have observed similar performance in boys and girls on phonological tasks and reported that there is no significant effect of gender on phonological processing abilities (Norrelgen, Lacerda, & Forssberg, 2001). There are varied research findings with regard to the influence of gender on processing speed tasks. While some investigators have reported a significant female advantage in rapid naming of digits and alphabets (Roivainen, 2011), others have not observed differences between males and females on rapid naming tasks (Wolff, Hurwitz, Imamura, & Lee, 1983).

On the whole, gender differences on phonological processing skills are reported to be significant for a variety of verbal tasks in favor of girls. However, the effect sizes of these differences are reported to be negligible. A meta-analysis of 165 studies reporting gender differences in verbal ability by Hyde and Linn (1988) revealed a weighted mean effect size of +0.11 indicating better performance by females. Following analyses of effect sizes, Hyde and Linn (1988) reported that although significant female superiority was reported in most studies, the magnitude of effect sizes were very small. Further, there was no effect of age on the magnitude of gender differences in phonological processing tasks.

Phonological Representation in Children with Communication Disorders

The effects of poor or underspecified phonological representations have been reported in children with a variety of developmental disorders. Poor phonological representations has been purported to be the cause of language and literacy difficulties of children with Phonological disorders (Anthony et al., 2011), Specific Language Impairment (SLI) (Elliott et al., 1990; Leonard & Eyer, 1996; Stark & Heinz, 1996; Tallal, 1990), Childhood Apraxia of Speech (CAS) (Marquardt et al., 2002; McNeill et al., 2009) and Dyslexia (Bortolini & Leonard, 2000; Catts, 1986; Elbro, 1996; Gathercole & Baddeley, 1990; Swan & Goswami, 1997).

1. *Speech Sound Disorder (SSD)*

According to Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5) (American Psychiatric Association, 2013), SSD is a diagnosis assigned to persons with problems in productive speech interfering with communication, which produces further impairment in functioning, and distress. This was earlier called as Phonological Disorder in the DSM-IV classification (Diagnostic and Statistical Manual of Mental Disorders, fourth Edition). The American Speech-Language-Hearing Association (ASHA) defined SSDs as an “umbrella term referring to any combination of difficulties with perception, motor production, and/or the phonological representation of speech sounds and speech segments (including phonotactic rules that govern syllable shape, structure, and stress, as well as prosody) that impact speech intelligibility". The term phonological disorder is used to refer to an impaired system of sound and sound patterns in spoken language (Bauman-Waengler, 2000). Grunwell (1987) hypothesized a neurolinguistic dysfunction at the phonological level in children with phonological disorder that reflected in a more central deficiency.

Research suggests that children with speech sound disorders may have difficulties in the storage and access of phonological representations, which makes them susceptible to literacy deficits. A study by Sutherland and Gillon (2005) investigated phonological representations in preschool children with speech impairment and the results showed that these children performed significantly poorer than typical children on receptive-based tasks that did not require verbal responses. Although phonologically based speech errors may resolve with intervention, some children with expressive phonological impairment continue to experience difficulties in literacy acquisition, particularly in phonological awareness and spelling (Gillon, 2002).

Although children with speech sound disorders are at significant risk for reading and writing difficulties, these children are not regularly evaluated for literacy skills. Furthermore, they are reported to be at risk for deficits in various aspects of phonological representations. It is thus important to test children with speech sound disorders for phonological representations, phonological awareness, as well as literacy skills.

2. Specific Language Impairment (SLI)

SLI is a disorder in which children fail to develop adequate language despite normal intelligence, adequate speech and language stimulation, and normal hearing sensitivity (Archibald & Gathercole, 2007). Language difficulties of children with SLI extend across early language skills important for decoding of reading and comprehension (Boudreau & Hedberg, 1999). Errors seen in speech may also be present in writing (Gillam & Johnston, 1992).

Phonology is one among the adversely affected domains of language in most children with SLI. Children with SLI were found to have poor phonological abilities when compared to age matched typically developing children with respect to accuracy of phonological segments, distinctive features, and phonological patterns and processes (Bortolini & Leonard, 2000). Investigators have reported poor repetition of nonsense words (Gathercole & Baddeley, 1990), misarticulations or deletion of phonemes from words (Leonard, 1982), difficulty in identifying words with similar phonemes (Bird & Bishop, 1992) and poor phonological awareness (Kamhi & Catts, 1986), thereby providing evidence for phonological deficits in children with SLI. Bortolini and Leonard (2000) observed that the segmental inaccuracies of children with SLI may be the result of unstable phonological representations underlying the articulatory maneuvers that cannot be accounted by limited peripheral articulatory skills.

Investigators have shown that children with SLI have deficient phonological representations compared to their typical counterparts (Edwards & Lahey, 1998, Maillart et al., 2004; Pennington & Bishop, 2009). Difficulty in novel word learning is also reported in children with SLI (Kan & Windsor, 2010). These deficits owing to less specified phonological representations were found to persist even when children with SLI were compared to typically developing children matched for receptive vocabulary (Maillart et al., 2004). On a multisyllabic word judgment task in French, a strong correlation was established between vocabulary and judgment abilities in both groups of children. Further, children with SLI were found to have difficulty in rejecting pseudo words which closely matched real words.

Various investigators have proposed that the phonological difficulties of children with SLI might be linked to the quality of their phonological representations. The underlying representations of children with SLI are hypothesized to be holistic, similar to that of younger typically developing children (Edwards & Lahey, 1998). There is considerable evidence of impaired speech perception in persons with SLI on tasks that tap subtle aspects of auditory processing (Elliott et al., 1990; Stark & Heinz, 1996; Tallal, 1990). Speech perception deficits impede the development of phonological representations, as a result of which, development of other grammatical aspects are affected (Leonard & Eyer, 1996).

Evidence of weaker phonological representations in children with SLI was demonstrated by Stackhouse, Vance, Pascoe, and Wells (2007) who observed that "accepting similar sounding non-words as the real word imply that the child's phonological representation of that word is *fuzzy* or inaccurate". Children with SLI were less sensitive to assimilatory changes in words with respect to consonant place of articulation (Claesson & Leitao, 2012; Marshall, Ramus, & van der Lely, 2010).

Based on error analysis of vowels in a nonword repetition task, Benders et al. (2007) reported that children with SLI have difficulties in encoding or storing phonological information and have greater number of vowel omission errors compared to typically developing children. Benders et al. (2007) observed that while typically developing children showed vowel omissions in the middle syllables, children with SLI omitted vowels in both initial and middle positions, implying that typically developing children showed both primacy and recency effects on nonword repetition tasks whereas children with SLI exhibited only recency effects. This was explained on the basis of the Trace Decay theory which suggests that the trace of the initial syllables decays much earlier to its retrieval (Baddeley, 1986).

3. Childhood Apraxia of Speech (CAS)

The hallmark of speech production in CAS include inconsistent vowel and consonant errors in repeated productions of syllables or words, deficits in coarticulatory transitions, and inappropriate prosody, particularly lexical stress (ASHA, 2007). It has been postulated that deficits in motor speech planning alone does not account for poor phonological awareness in children with CAS. Instead, indistinct phonological representations and/or poor access to extant phonological representations are attributed as factors underlying difficulties in the areas of speech, language and literacy in CAS (Marion, Sussman, & Marquardt, 1993; Marquardt et al., 2002). Poor quality of phonological representations in children with CAS is reported to result in the inability of these children to monitor motor performance (Marion et al., 1993). Sutherland and Gillon (2005) expressed that there is diminished phonological representation system in children with CAS. McNeill et al. (2009) supported this view based on their study using a phonological representation judgment task, wherein they observed children with CAS have deficits in reading and phonological representations in addition to the commonly acknowledged limitations in verbal motor planning.

4. *Dyslexia*

Phonological impairment is most commonly implicated as the cause for developmental dyslexia. Children with dyslexia are reported to fail in developing fine-grained phonological representations, which hinders the development of phoneme – grapheme correspondence (Manis et al., 1997). There are increasing reports of significant correlation between the performance of children with dyslexia on tasks of phonological awareness and the quality of phonological representations. For example, Elbro et al. (1998) studied children of dyslexic parents and reported that the quality of phonological representations as measured on vowel articulation in kindergarten was a good predictor of phoneme awareness in the second grade.

There are also evidences to support the concept of immature phonological representations in children with dyslexia. Implicit phonological representations were examined in 11-13 year old children with dyslexia using tasks such as lexical gating, priming and syllable similarity (Boada & Pennington, 2006). Results of this study revealed immature phonological representations in children with dyslexia compared to both chronological age matched and reading age matched controls, thereby implicating deficits at a level underneath phonological awareness in these children. The impact of poorly specified or inaccurate representations may be maximally seen in children with underlying difficulties in processing phonological information. Imprecise or 'fuzzy' phonological representations and motor programs are reported to result in imprecise word productions and also difficulties in multisyllabic word repetition (Catts & Kamhi, 1999; Leitao, 2003). Further, poor phonological representations continue to have adverse effects on literacy skills in such children long after their speech and language difficulties appear to be resolved (Nathan, Stackhouse, Goulandris, & Snowling, 2004). Vellutino et al. (2004) observed that children with dyslexia have a striking deficit in speech production despite adequate speech perception abilities.

Investigators have postulated that poor phonological representations in individuals with dyslexia that interferes in efficient encoding and retrieval of phonological information might be linked to the deficits in vocabulary acquisition (Gathercole & Baddeley, 1990; Wolf & Obregon, 1992). Phonological awareness skills in children with dyslexia rely on the precision of the underlying phonological representation and also the linguistic level to be operated upon (Swan & Goswami, 1997). There was no clear indication of gross linguistic deficits in majority of the participants with dyslexia, which led to the development of a metalinguistic hypothesis. According to the metalinguistic hypothesis, the development of underlying phonological representations is normal in children with dyslexia, however, explicit access to the same for developing literacy is affected (Boada & Pennington, 2006).

Slower phonological processing abilities are reported in poor readers of Indian alphasyllabaries like Kannada (Ramaa, Miles, & Lalithamma, 1993; Nag-Arulmani, 2003; Nag & Snowling, 2011), Hindi (Gupta, 2004), Bengali (Nag & Sircar, 2008) and also Korean (Kim, 2009; Kim & Davis, 2004). Investigators have reported co-occurrence of deficits in reading and rapid automatized naming in both consistent and inconsistent alphabetic languages (e.g., de Jong & van der Leij, 2003; Lovett, 1987; Nikolopoulos, Goulandris, Hulme, & Snowling, 2006; Wimmer, Mayringer, & Landerl, 1998), logographic Chinese (e.g., Ho, Chan, Tsang, & Lee, 2002) and also the Kannada alphasyllabary (Nag & Snowling, 2012).

Assessment of Phonological Representation

Numerous tasks have been used by investigators to study the phonological representations, both in typically developing children and those with developmental disorders. Tasks like picture naming (Bridgeman & Snowling, 1988; Elbro et al., 1996; Fowler & Swainson, 2004; Foy & Mann, 2001; Gray, 2004; Roberts, 2005), word and nonword imitation (Fowler & Swainson, 2004), lexical decision (Edwards & Lahey, 1996; Maillart et al., 2004); gating paradigm (Dollaghan & Campbell, 1998; Metsala, 1997a, 1997b) and correcting mispronunciations (Elbro et al., 1998; Elbro & Petersen, 2004; Foy & Mann, 2001) have been used to gain insights about phonological representations in children. Among the many tasks used to assess the accuracy of phonological representations, evaluation of articulation accuracy has been most commonly used by researchers. These tasks facilitate evaluation of the sublexical units of words at the level of phoneme and/or the articulatory gestures involved in their production which are indices of precise phonological representations (Liberman, 1999). However, most of these tasks require verbal responses and hence remain challenging when administered on very young children. They also deter the separation of representation from skill in motor programming, planning and production.

Conflicting findings reported across studies using the gating paradigm (Wesseling & Reitsma, 2001) reflects on the utility of the task as a measure of phonological representations. While Dollaghan (1998) and Montgomery (1999) reported similar performance of children with SLI and chronological age matched typical children on gating task for familiar words, Dollaghan (1998) found that children with SLI have difficulty in identifying novel words. These findings indicate that children with SLI have greater difficulties in building phonological representations.

Naming of multisyllabic words are also purported as measures of tapping stored phonological representations (Baker & Munro, 2011). Picture naming tasks involve accessing semantic representations and the motor programs associated with lexical representations followed by activation of the motor plan for the articulatory gestures for naming. Thus, naming tasks depend on both output processing and stored phonological representations.

Performance in nonword reading task is a clear indicator of application of phonological rules in children (Gough & Tunmer, 1986) in addition to understanding the nature of the underlying phonological representations (Snowling, 2000). Hester and Hodson (2004) assessed the relative strength of phonological representation in third grade children through multisyllabic real word production, multisyllabic nonword repetition, and a complex phonological manipulation task – “pig Latin” (Pennington, Van Orden, Smith, Green, & Haith, 1990). The role of phonological representation in reading abilities was compared with the role of working memory, nonverbal intelligence and receptive vocabulary. The investigators reported a significant positive relationship between multisyllabic real word production and phonological manipulation tasks, thereby strengthening the assumed contribution of underlying representations to explicit phonological awareness tasks. The findings of this study contribute to the understanding of the processes underlying decoding of reading in beginners. Hester and Hodson (2004) also proposed that there is a need to develop diagnostic tools, utilizing multisyllabic stimuli, in order to facilitate assessment of phonological representation during the later school years.

The need to examine phonological representations in children with speech sound disorders paved way for the development of receptive based speech tasks to measure the precision of phonological representations. Several receptive tasks have been used in the past to measure precision of phonological representations. For example, judging whether a word uttered by an examiner or puppet was articulated correctly (Carroll & Snowling, 2004; Rvachew et al., 2003; Sutherland & Gillon, 2007), choosing the most accurate pronunciation among a number of tokens produced by an examiner or puppet (Fowler & Swainson, 2004), speech discrimination tasks requiring participants to point to a picture corresponding to a word uttered by an examiner from an array of distracters that differ by a single phoneme (e.g., Elbro & Petersen, 2004; Foy & Mann, 2001) and lexical decision (Claessen et al., 2009). Interpretation of results derived from perceptual studies can be from the standpoint of either a perceptual account or a featural/phonological account. However, interpretation based on phonological features is regarded as a better choice because of its capacity to provide information on the developing phonological representations, thereby offering a link between perception and production (Van der Feest, 2007).

The phonological distinctness of vowels in lexical representations has been studied using the mispronunciation-detection task (e.g.: Mani & Plunkett, 2007). Simon, Sjerps, and Fikkert (2014) postulated that if the phonological representations of vowels are sufficiently detailed, then a common lexical item with vowel substitution will be rejected, owing to disparity in the stored representation of the target vowel and the perceived phonetic realization. Using a mispronunciation detection task, they showed that children aged 9-12 years successfully rejected more than 90% of mispronunciations indicating the availability of sufficient phonemic details in their lexical representations to detect mispronunciation of a single vowel. It was also found that children took longer than adults to perform this task suggesting a developmental trend in the ability to detect vowel mispronunciations. Research by Nazzi (2005), who tested children on detection of vowel versus consonant mispronunciations, has shown that not all mispronunciations yield equal effects. White, Morgan, and Wier (2005) showed that the effects of mispronunciations increased with increase in the number of mispronounced features. Van der Feest (2007) reported larger effects of place mispronunciations than voice mispronunciations in Dutch. Similar findings have been confirmed by White et al. (2005) who also found a slightly larger effect for place than for voice mispronunciations in English.

All tasks are not equally helpful in the assessment of phonological representation. For example, Anthony et al. (2010) attempted to assess phonological representations by using a variety of tasks in monolingual English population. Results showed that spontaneous labeling of pictures in gating tasks was a poor measure of phonological representation. On the other hand, tasks like rapid naming, articulation accuracy and articulation judgment proved to be effective in the assessment of underlying phonological representations. Analogous to this, Anthony et al. (2011) assessed phonological representation of Spanish in Spanish- English sequential bilinguals and reported similar findings. Although these tasks may tap underlying phonological representations, Anthony et al. (2010) cautioned that they are heavily influenced by other phonological abilities and hence there is a need to have several measures for different aspects of phonological representation. This, in turn, would contribute in understanding the role of phonological representations as being distinct from skills such as articulation, speech perception, RAN, and phonological awareness.

Phonological awareness tasks are literacy dependent and hence may not be suitable to predict the potential of preschoolers in developing reading difficulties later on. The extent of lexical differentiation has been hypothesized to be a potential measure as it is less dependent on literacy knowledge. Empirical findings in the literature provide evidence to show that the process of lexical differentiation can be measured. Metsala (1997a, 1997b) used the gating paradigm and showed that the lexical representations are holistic in young children and poor readers when compared to that of older children and adults. Older children and adults could correctly identify words with less auditory input compared to young children, thereby demonstrating that gating task is a measure lexical differentiation. Similarly, cued word fluency and non-word repetition (Fowler, 1991) could be suitable tasks in this regard. Cued word fluency task is a measure of lexical retrieval using partial phonological information. On the other hand, differences in performance on a non-word repetition task are likely to be associated with individual differences in the quality of speech encoding, retention, and production and, hence, the nature of phonological representations in long-term memory (Gathercole, 1995).

An implicit phonological awareness task first proposed by Messer (1967) was later validated by Lance, Swanson, and Peterson (1997). In this task, a pair of nonsense words in which one of the stimuli violated the phonotactic constraints of English was presented to the participants. They were instructed to identify the stimulus in the pair that consisted of permissible consonant combinations in English. The results showed significant correlation between this task and other explicit phonological awareness tasks, a multisyllabic word production task, and two reading measures. Lance et al. (1997) expressed that the participants may not have relied on segmental representation at the phonemic level to complete the task and hence, might be a holistic measure of phonological awareness.

Despite the lack of clarity regarding the contributions of quality of phonological representations to phonemic awareness and reading difficulties, the results of three studies by Wesseling and Reitsma (2001) substantiated the relevance of individual variations in factors such as linguistic abilities, non-word repetition, and phonological awareness in envisaging emergent literacy skills. They further demonstrated that testing various skills in preschoolers and interpreting the relations between them should be exercised with caution owing to instability of results.

Elbro et al. (1998) used an articulatory correction task in beginning kindergartners (specifically asked children to correct a puppet's erroneous word production) along with letter identification and phoneme awareness tasks and reported that these tasks were exceptional predictors of reading skills in grade two. Articulation correction tasks are considered as very sensitive measures of phonological representations as it requires highly accurate articulatory abilities. Further, quality of phonological representations in young children as assessed in articulation correction tasks are significant predictors of phonemic awareness over the kindergarten year (Elbro, 1998).

The influences of stimulus characteristics and test characteristics in measuring precision of phonological representations have also been well documented. Articulation accuracy for long, less familiar and phonologically complex words is regarded as a better indicator of individual variations in phonological representations compared to short, familiar and phonologically simple words (Fowler & Swainson, 2004; Swan & Goswami, 1997). The representations for long words are expected to be incomplete, fuzzy, or inaccurate compared to shorter words as it is imperative for long words to have several phonological features in the lexicon. Similarly, low frequency words in a language are more likely to have poorly specified underlying representations as children generally have fewer opportunities to encounter these words (Fowler & Swainson, 2004). On similar lines, unstressed syllables (Blasdell & Jensen, 1970) and complex consonant clusters (Vihman, 1980) are proven to be sensitive measures of individual differences in the accuracy of phonological representations owing to a high probability of committing articulatory errors on these stimuli.

Connected speech samples are reported to provide an in depth analysis of the precision of phonological representations as compared to single word utterances (Andrews & Fey, 1986; Anthony et al., 2010; Morrison & Shriberg, 1992) The importance of using connected or continuous speech samples for the assessment of phonological accuracy in children have been widely acknowledged in the literature. In the recent years, sentence imitation tasks are used increasingly as a valuable tool for both clinical assessment and research. Sentence imitation has been used to gain insights about linguistic abilities in both typical children and children with language impairments (Conti-Ramsden, Botting, & Faragher, 2001; Ebert, 2014; Leclercq, Quemart, Magis, & Maillart, 2014; Vinther, 2002). Sentence repetition tasks are also reported to contribute to the understanding of underlying mechanisms in processing language. For example, working memory (Devescovi & Caselli, 2007; Stokes, Wong, Fletcher, & Leonard, 2006), auditory memory and written memory (Rummer, Schweppe, & Martin, 2013) and memory span (Ebert, 2014) are reported to play an essential role in the differential diagnosis of developmental language disorders (Devescovi & Caselli, 2007; Leclercq et al., 2014). Sentence repetition tasks have been used to address issues related to limitations in storage capacity or linguistic representations in persons with Specific Language Impairment (SLI). Various researchers (Mainela-Arnold, Evans, & Coady, 2010; Mainela-Arnold, Misra, Miller, Poll, & Park, 2012; Polisenska, Chiat, & Roy, 2015) have used verbal recall tasks and concluded that the storage capacity is inseparable from the linguistic representations in persons with SLI. However, studies using sentence imitation tasks as a protocol to understand phonological issues is scarce.

Studies comparing imitated tasks (using word or sentences) with spontaneous speech productions have yielded contradictory findings. While few studies have reported greater errors in spontaneous speech as opposed to imitated utterances (DuBois & Bernthal, 1978; Faircloth & Faircloth, 1970; Smith & Ainsworth, 1967), others have reported no difference between spontaneous speech productions and imitated speech samples (Paynter & Bumpas, 1977; Siegel, Winitz, & Conkey, 1963). Understanding of a child's speech sound system warrants the use of both standardized, norm referenced measures as well as non-standardized measures. Few standardized assessment tools have used sentence tasks, either spontaneously elicited or imitated. Snyder (2010) demonstrated the advantages of a sentence imitation task over spontaneous speech in understanding the speech sound inventory in children with speech sound disorders. Contrary to the view expressed by a few investigators that connected speech better represents the speech sound errors (e.g.: DuBois & Bernthal, 1978; Klein, 1984; Morrison & Shriberg, 1992), Snyder (2010) reported that imitated sentence task provided greater information about the nature of speech sound errors in children. Snyder (2010) compared three tasks, namely identification of single word, connected speech and sentence imitation in three children with speech sound disorders using independent analyses, relational analyses, phonological error patterns and percentages of consonant correct and observed that imitated sentence task yielded a comprehensive picture of phonological error patterns and percentages of consonants correct followed by single word identification and connected speech. Both single word identification and sentence imitation tasks facilitated the inclusion of all the target speech sounds. Further, sentence task were less time consuming in terms of administration and transcription compared to connected speech thereby adding to the efficiency of the task.

Sentence imitation tasks are also reported as useful measures in the evaluation of phonological representations. Some of the studies implicate the contribution of phonological representations in immediate sentence recall in addition to semantic information (Anderson, 1971; Hayes-Roth & Hayes-Roth, 1977; Moeser, 1974; Sachs, 1974). However, the role of semantic and syntactic aspects in sentence recall is well reported, whereas the contribution of phonological representations has been highly debated. The role of phonological information is widely acknowledged with respect to memory for unrelated lists such as letters, numbers, words, or nonwords (e.g., Conrad & Hull, 1968), but not for related words in the context of a sentence (Alloway, 2007; Potter & Lombardi, 1990). Potter and Lombardi (1990) proposed the 'Conceptual Regeneration Hypothesis' which attributes the process of sentence recall entirely to the semantic, conceptual and lexical identity excluding the phonological domain. Investigations on the relationship between phonological representations and sentence recall by Katz (1998), Rummer and Engelkamp (2001) aided in rejecting the Conceptual Regeneration Hypothesis. Few other studies reported that auditory modality facilitates phonological representations (Rummer & Engelkamp, 2001). Balota, Cowen, and Engle (1990) reported that the final words in a sentence contain greater phonological information compared to the words in the middle of the sentence. Studies on persons with brain damage (Martin, Shelton, & Yaffee, 1994; Hanten & Martin, 2000) have provided neuropsychological evidences for phonological contributions to sentence memory. Park (2002) pointed to the role of both semantic and phonological representations in short term recall of sentences. In an experiment conducted by Park (2002), sentences were presented either in rapid serial visual presentation or in the auditory mode with semantically related or both semantically and phonologically related lure words. Results revealed greater intrusions of both semantically and phonologically related lure words than only semantically related lure words in the auditory presentation. Further, encoding of phonological information was found to occur at all positions of a sentence and was maintained until the sentences were recalled. Other studies followed with modified intrusion paradigm of Potter and Lombardi (1990). These studies highlighted the role of phonological representations in short term sentence recall (Eg: Rummer & Engelkamp, 2003; Schweppe, Rummer, Bormann, & Martin, 2011). Melby-Lervag and Hulme (2010) reported similar findings based on a vocabulary training program in children.

Research in the area of phonological representations has been restricted to individuals from only a few linguistic backgrounds. The utility of several tasks in the assessment of phonological representations in various languages has been studied. However, cross-linguistic research in this area is scarce and little is known about the efficacy of the tasks in various languages. Caravolas and Bruck (1993) reported a strong influence of linguistic features on the phonological representations in a cross-linguistic study in Czech-English. Anthony et al. (2010) studied incipient Spanish-English bilingual preschoolers and reported that phonological representations are organized similarly in both monolingual English-speaking preschoolers as well as Spanish dominant incipient bilingual preschoolers. Fletcher, Hogben, Neilson, Lalara, and Reid (2015) developed a phonological representations task that was culturally relevant for children whose native language was Anindilyakwa and reported that the task was reliable and had significant correlation with three measures of phonological awareness and phonics in English.

Studies on Phonological characteristics in Indian Languages (including Kannada Language)

Despite few studies that have addressed the phonological characteristics of Kannada – English bilingual children in a syllable timed language like Kannada (a Dravidian language spoken in Southern part of India) as the dominant language, the results remain vague. The perceptual stability and the primacy of the syllable in Kannada language is addressed from various angles in few studies. Phonemic awareness is reported to be slower to develop in Kannada-English bilingual children (Prakash & Rekha, 1993; Prakash, Rekha, Nigam, & Karanth, 1993).

There are however, very few standardized tools/tests in Kannada which are sparse and address peripheral issues of phonological representation but not target the core phonological representation (Eg: Reading Acquisition Profile in Kannada by Prema, 1997). Issues related to phonological representation have only been inferred based on tasks related to phonological awareness, early literacy, reading and writing (Prakash et al., 1993; Prakash, Chandana, & Suma, 2001; Padakannaya, Rekha, Vaid, & Joshi, 2002). Particularly, the concept of phonological representation has been addressed in relation to orthographic representation. Nonetheless, literature suggests that phonological representation of a spoken word is different from its orthographic counterpart (Taft, 2006). Thus, there is a need to study phonological representations in the context of oral language which has consequent implications in emergent literacy and the development of reading and writing.

An attempt in this direction was made by Priya and Manjula (2016a) who reported on the use of articulation judgment tasks to gain insights about the underlying phonological representations in typically developing Kannada speaking preschoolers. Articulation judgment tasks were carried out separately for vowels and consonants and a significant age effect was reported in the ability to detect mispronunciations of both vowels and consonants. Further, the performance of preschool children varied between vowels and consonants indicating differences in the development of or access to underlying representations for different types of speech sounds. These observations were in consonance with similar findings in literature (Altvater-Mackensen, Van der Feest, & Fikkert, 2014; Mani, Coleman, & Plunkett, 2008; Mani & Plunkett, 2010a, Van der Feest, 2007). Differences were also observed within the features of vowels and consonants, thereby indicating that phonological representations include detailed information related to both phonemic and sub-phonemic aspects of a word (Altvater-Mackensen & Mani, 2013, 2015; Mani & Plunkett, 2010b; White & Morgan, 2008). In addition to the developmental effects in the perceptual aspects of vowels and consonants, there is a wide body of research on acquisition and mastery of different speech sounds (Deepa & Savithri, 2010; Donegan, 2013; Dyson & Paden, 1983; Hua & Dodd, 2000; Otomo & Stoel-Gammon, 1992; Prathima & Sreedevi, 2009; Selby, Robb, & Gilbert, 2000; Shishira & Sreedevi, 2013; Sushma & Sreedevi, 2013). In general, vowels are acquired and mastered before consonants. In addition, there are differences within the categories of vowels and consonants based on various dimensions. Among the vowels, differences are reported along the dimensions of tongue height and tongue advancement. Similarly, acquisition of consonant phonemes varies in terms of place of articulation, manner of articulation and voicing.

Phonotactic rules describe the shape and order of sounds in words (Velleman, 2002). Syllable structure plays an important role in planning and production of speech (MacKay, 1972). During the developmental years, typically developing children implicitly learn the phonotactic patterns and constraints of a language. Many investigators have addressed the need to examine phonotactics in children with disordered phonologies (Bernhardt, 1994; Bernhardt & Stoel-Gammon, 1994;

Velleman, 1998; Velleman, 2002) as they have limited phonetic and phonotactic repertoire. Phonotactic analysis of speech in children provides a greater insight into phonological aspects compared to the information obtained from the phonetic repertoire alone (Velleman, 2002). Knowledge of phonotactics helps in the treatment planning for children with praxis breakdown.

In the Indian context, phonotactic patterns were explored in typically developing children speaking various Indian languages like Kannada (Rupela & Manjula, 2006), Telugu (Neethipriya & Manjula, 2007) and Hindi (Shukla, Manjula, & Praveen, 2011) during the developmental years. Rupela and Manjula (2006) studied the phonotactic development in 30 typically developing children aged 0-5 years. Elicited spontaneous speech samples and word imitations were used as stimuli and the analyses of word and syllable shapes were carried out based on 100 fluent utterances selected from samples of each child. They observed that certain word shapes were acquired earlier, for example, CV syllables were achieved prior to VC and CVC syllables. Cs occurred rarely and were acquired in children between the age ranges of 0-18 months. Vs were also found occasionally but they occurred more frequently than Cs. The occurrence of medial geminates were the highest followed by medial non-geminated clusters, initial clusters and medial three-sound clusters. Monosyllables occurred rarely in children’s speech and they were found to occur from 24 to 60 months. Amongst word shapes, disyllables occurred most frequently followed by trisyllables and multisyllables. Overall, all the syllables in Kannada language described in adult phonology (Hiremath, 1980) were found to be acquired by children by the age of 12-18 months, although the frequency of occurrence varied widely. CV syllables were most common followed by VC and CVC syllables.

Most of the studies have derived the nature of phonological representations from immediate sentence recall based on analyses of articulatory or phonetic errors, phonological processes or in terms of place, voicing and manner measures. However, the use of phonotactic analysis as a probable measure to understand the developing phonological representations in children has not been vastly explored. Phonotactic analysis, in terms of various word shapes and syllable shapes, of the imitated samples of children during their developmental years will help delineate the status of the phonological representations and its accessibility in children. Immature or emerging representations in younger children may render the task of producing complex word shapes or syllable shapes difficult resulting in production of simpler forms. It may thus be hypothesized that younger children produce simpler word shapes and syllable shapes compared to their older counterparts. These subtleties may not be characterized in a spontaneous speech task and may be best understood in an imitation task.

A sentence imitation task provides an opportunity to analyze imitated utterances with respect to the corresponding target patterns. Further, time constraints in collecting as well as analyzing spontaneous speech productions from young children makes sentence imitation a preferred choice of test, particularly in a clinical situation. A recent study by Priya and Manjula (2016b) compared the development of phonotactic patterns in an attempt to understand the nature of phonological representations. A sentence imitation task was administered on 80 typically developing Kannada speaking children in the age range of 3 to 5 years and the responses were analyzed for various word shapes and syllable shapes. The results indicated a developmental trend for phonotactic patterns thereby substantiating the utility of sentence imitation in the assessment of phonological representations.

Summary

In summary, phonological representation is a crucial and an essential feature which facilitates the growth of oral and written language. There is growing awareness about the significant contributions of phonological representations in the development of phonological awareness and consequently, literacy skills during the preschool and elementary school years (Elbro et al., 1998; McCardle et al., 2001; Vihman & Croft, 2007; Snowling, 2000). Of the various representation related measures, quality and accessibility of the underlying phonological representations are considered to be of greater significance.

It is also evident that poor phonological representation is at the core of various deficits seen in children with SSD, SLI, CAS and dyslexia, among others. Poor phonological representation or deficits in accessibility to these representations hampers development of various aspects of phonology (phonological process, phonological awareness, suprasegmentals etc) which in turn has confounding effects on the development of other aspects of language and literacy skills. Sutherland and Gillon (2005) reported that performance on phonological representation tasks could predict phonological awareness, reading and spelling difficulties. The assessment of phonological representations can hence be considered as very essential in the comprehensive evaluation of these disorders. Assessment of phonological representation has included tasks that have proved effective in targeting the various dimensions of phonological representation. Inclusion of phonological representation in the assessment battery of children with speech and language impairments will shed more light on the processing abilities of these children. This has greater implications in the long term management of children with these developmental conditions. Thus far, however, there are no tools or test batteries standardized for the assessment of phonological representation although several tasks have been delineated to measure the accessibility and precision of these representations in typically developing children and also children with various language impairments. A comprehensive assessment battery should include tasks of phonological representations in order to understand the underlying processing mechanisms which will in turn facilitate treatment planning. This is especially true in the Indian context.

METHOD

The aim of the study was to develop and standardize a test battery for the assessment of phonological representations in Kannada speaking typical children in the age range of 3 to 5 years. Further, the test was also administered on clinical population with the following developmental disorders:

A. Children with Speech Sound Disorder (SSD)

B. Children with Specific Language Impairment (SLI)

C. Children with Childhood Apraxia of Speech (CAS)

D. Children at risk for Dyslexia

Objectives of the study

I. To investigate and study the following in typically developing native speakers of Kannada in the age range of 3-5 years:

1. The effect of gender on the performance in each of the following tasks:

   A. Articulation Judgment Test for: a) Vowels & b) Consonants

   B. Articulation Correction Test for: a) Vowels & b) Consonants

   C. Sentence Imitation Test

   D. Rapid Automatized Naming Test for: a) Nouns b) Verbs & c) Size

2. The effect of age on the performance in each of the following tasks:

   A. Articulation Judgment Test for: a) Vowels & b) Consonants

   B. Articulation Correction Test for: a) Vowels & b) Consonants

   C. Sentence Imitation Test

D. Rapid Automatized Naming Test for: a) Nouns b) Verbs & c) Size

3. The effect of stimuli on the performance in each of the following tasks:

    A. Articulation Judgment Test

    B. Articulation Correction Test

    C. Sentence Imitation Test

    D. Rapid Automatized Naming

II. To investigate and compare the performance of children with the following developmental disorders with that of the typically developing children in various subsections of the test battery:

    A. Children with Speech Sound Disorder (SSD)

    B. Children with Specific Language Impairment (SLI)

    C. Children with Childhood Apraxia of Speech (CAS)

    D. Children at risk for Dyslexia

Research Design

A cross-sectional normative research design and standard group comparison was used to accomplish the objectives of the study. A 'Between Subject Design' was used to compare the phonological representations across typically developing participants in different age groups, and 'Within Subject Design' was used to analyze the performance of participants on various subsections of the test battery. Standard group comparison was used to compare the performance of participants in the Clinical group with the normatives established on typical group of participants.

The study was carried out in 5 phases:

Phase 1 Development of test battery for the assessment of phonological representations in typically developing native speakers of Kannada in the age range of 3-5 years.

Phase 2 Conduct Pilot study to check for the validity of:

a) stimuli selected
b) administration of the test battery
c) scoring procedures used in the test battery

Phase 3 Modification of the test battery based on the results of pilot study conducted in Phase 2.

Phase 4 Standardization of the test battery by administering on 240 typically developing native speakers of Kannada divided into four age groups (>3;0 - ≤3;6; >3;6 - ≤4;0; >4;0 - ≤4;6 and >4;6 - ≤5;0 years) with 60 participants in each age group (30 Boys & 30 Girls).

Phase 5 Administration of the test battery on following clinical groups to test for its utility:

a) Children with Speech Sound Disorder (SSD) (11 participants: 5 Boys & 6 Girls)
b) Children with Specific Language Impairment (SLI) (9 participants: 8 Boys & 1 Girl)
c) Children with Childhood Apraxia of Speech (CAS) (3 participants: 2 Boys & 1 Girl)
d) Children at risk for Dyslexia (7 participants: 5 Boys & 2 Girls)

Phase 1: Development of Test Battery for the Assessment of Phonological Representations in Typically Developing Native Speakers of Kannada in the Age Range of 3-5 Years

There are no standardized assessment tools available in Kannada language to measure phonological representations in preschool children. Hence, an extensive review of the existing literature and resources was carried out and tasks that were reported to tap various dimensions of phonological representation were shortlisted. The subsections of the test battery were framed in Kannada language one by one considering the appropriateness of the tasks to address various dimensions of phonological representation in typical children aged 3 to 5 years. The stimuli for tasks in each of the subtests were developed in Kannada language.

The details of the subsections included in the test battery were as follows:

A. Articulation Judgment Test for: a) Vowels & b) Consonants
B. Articulation Correction Test for: a) Vowels & b) Consonants
C. Sentence Imitation Test
D. Rapid Automatized Naming Test for: a) Nouns b) Verbs & c) Size
E. SHWA test (Test for Knowledge of Orthographic Principles)

A. Articulation Judgment Test - a) Vowels and b) Consonants

Receptive based speech tasks were developed by researchers to assess phonological representations in children with speech sound disorders as these children are known to have difficulty in expressive tasks. Several variants of receptive tasks were used by researchers to measure phonological representations (e.g: Anthony et al., 2010; Carroll & Snowling, 2004; Claessen et al., 2009; Mani & Plunkett, 2007; Rvachew et al., 2003; Simon et al., 2014; Sutherland & Gillon, 2007). The general principle of these tasks was that if listeners have a well developed and precise representation of a particular phoneme, then presentation of a familiar lexical item in which one of the phonemes is replaced by another phoneme will be rejected as it creates a mismatch between the perceived phonetic realization and the stored representation of the phoneme.

In the test battery developed in this study, vowels and consonants were considered separately as few studies observed that mispronunciation detection tasks for vowels and consonants yield different results (Nazzi, 2005; Priya & Manjula, 2016a), probably because segmental features of consonants are different from that of vowels and vowels also have a greater degree of normalization than consonants in perception and display relatively more variability across speakers (Peterson & Barney, 1952).

A receptive picture vocabulary test was developed as a control task to ensure that the stimuli used for Articulation Judgment Test and Articulation Correction Test were within the receptive vocabulary of participants in the age range of 3-5 years. The words in KPVT – A Screening Picture Vocabulary Test in Kannada which was developed by Sreedevi (1988) had norms established on children speaking Kannada as their native language in the age range of 3-6 years and studying in Kannada medium schools. However, KPVT was not suitable for this study for two reasons: a) the test did not include phonologically complex words b) children chosen for the study were native Kannada speakers studying in English medium schools. Hence, the test material was developed by the investigator including phonologically complex words with clusters which were within the vocabulary of Kannada speaking children in the age range of 3-5 years that could also be depicted in the form of pictures. The aim of the test was to present each target stimuli with two semantically related distracters in the form of pictures.

Selection and Preparation of Stimuli

Step1: Initially, a list of 80 words with clusters was compiled by the investigator considering the vocabulary of children speaking Kannada language in the age range of 3 to 5 years and also referring to standard Kannada textbooks for kindergarten and nursery classes. The list comprised of both native Kannada words as well as common words borrowed from English which are considered as nativised Kannada words (e.g. /ʃərṭƱ/ 'shirtu' – the nativised form of the English word /ʃərṭƱ/ 'shirt') (Prasad & Rao, 2011)[1]. Nineteen words with clusters were selected from the Kannada Diagnostic Photo Articulation Test (Deepa & Savithri, 2010) which was standardized for Kannada speaking children in the age range of 2-6 years by these investigators. The word list thus compiled was subjected to check for familiarity of the stimuli in terms of the nomenclature and the concept by presenting these words in picture form for an identification task to 60 Kannada speaking children in the age range of >3;0 - ≤ 3;6 years (this being the youngest group of participants of the study). The investigator named the words one by one and the children were asked to identify an appropriate picture from a set of three pictures for each stimulus that was named. Accuracy of

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[1] Prasad and Rao (2011) studied the phenomenon of code switching and borrowing in 6 to 8 year old monolingual children whose native language was Kannada and who were studying in Kannada medium schools. They reported that children often switched languages (from Kannada to English) for particular word class like nouns – names of vegetables (carrot), clothes (shirt), profession (doctor) etc. They provided evidence for use of words which are considered as nativised forms of the borrowed words owing to their consistent and frequent use in routine conversations. In case of borrowal from English to Kannada, the words are nativised by the addition of the vowel 'u' to the borrowed word as the phonotactics of Kannada does not permit consonant sound at the end of words.

responses by the children was ascertained by the investigator by questioning the caregivers regarding familiarity of stimulus to the child and usage of the same in his/her conversation. Stimuli that were found to be familiar to at least 70% of the children were considered as the criteria and in this way, a total of 50 words were shortlisted. These 50 word list was further given to 5 adult native speakers of Kannada language, who were asked to rate each word in the list to mark the word for familiarity and appropriateness to Kannada speaking children in the age range of 3 to 5 years. A three-point scale was used to check for familiarity as follows: 1 = most familiar, 2 = familiar and 3 = not familiar. A two-point scale was used to check for appropriateness as follows: 1 = appropriate, 2 = inappropriate. The stimuli rated as ‘most familiar’ and ‘appropriate’ were chosen for the study and in this way a total of 33 stimuli words were chosen.

Following this, a list of two semantically related words were chosen as distracters for each target word. The distracters were also subjected to familiarity rating by the same 5 adult native speakers of Kannada language. They were instructed to rate the stimuli on a binary scale as ‘familiar’ or ‘not familiar’. All the stimuli were rated as familiar and were thus, included in the test.

Step 2: The picture stimuli to depict the 33 word targets and the corresponding distracters were drawn as computerized two dimensional pictures by a graphic designer. These computerized pictures were printed on 5” * 7” cards and presented to 5 adult native speakers of Kannada language to rate for ambiguity of the pictures on a three-point scale as follows: 1 = least ambiguous, 2 = ambiguous and 3 = most ambiguous.

Based on the responses from the 5 adult native speakers of Kannada language, the pictures were modified until all the pictures were rated as ‘least ambiguous’ and the same were retained for the study. The 33 target words included in the Receptive Picture Vocabulary Test were used to further develop two stimuli lists; one each for assessing articulation judgment abilities for vowels and consonants in Kannada[2].

a) Test for Articulation Judgment of Vowels

To prepare the stimuli list with vowel modifications, one vowel in each of the 33 target words which were true words was modified to make another set of 33 nonwords with vowel modifications. In principle, only vowel substitutions were used to modify the word, while maintaining the syllable shape of the words as in the true word. For example, the final vowel /I/ in the meaningful target word /IḍlI/ (idli) was changed to /Ʊ/ resulting in a nonword /IḍlƱ/ (idlu). In this way, the final list for this test included a total of 66 stimuli in which 33 stimuli were true words (with no vowel change) and 33 stimuli were nonwords due to substitution of a vowel in the true word.

When vowels were substituted in order to prepare the 33 nonword list, it was not possible to include all combinations of substitution patterns. The substitution of vowels varied in terms of tongue height (low, mid and high) and tongue advancement

[2] Kannada is a Dravidian language spoken majorly in Karnataka which is one of the southern states of India. Kannada has a phonological system which consists of 43 phonemes in total (Upadhyaya, 1972). There are five short and five long vowels in the vowel system of Kannada. The basic consonant system of Kannada consists of 33 consonants including stops, affricates, fricatives, nasals, laterals, flaps and continuants. The stop consonants and affricates include both voiced and unvoiced counterparts, and also aspirated versions. Appendix 1 gives the details of vowels and consonants in Kannada language. The writing system of Kannada is an alphasyllabary in which the syllable holds a prominent position. The syllabic units include both consonant and vowel phonemes in an embedded form (Nag, 2011). In this study, ‘*vowels*’ and ‘*consonants*’ as ‘*phonemes*’ are operationally defined as the vowel portion and consonant portion of the embedded syllable respectively.

(front, central and back). Table 1 shows the number of occurrence of various substitution patterns that were made in preparation of the nonword list. Tables 2 and 3 gives the details of vowel substitutions made with respect to tongue height and tongue advancement respectively.

Table 1

Number of Occurrence and Types of Vowels Substituted in the True Words in order to prepare Nonword list

		Vowels Substituted (Nonwords)				
		a	I	Ʊ	e	o
Target words (True words)	a		6	5	3	
	I	3		3	2	
	Ʊ	3	2			
	e		1	2		2
	o		1			

Table 2

Number of Occurrence of Vowels Substituted with respect to Tongue Height in the True Words in order to prepare Nonword list

		Vowels Substituted w.r.t tongue height (Nonwords)		
		Low (a)	Mid (e)	High (I, Ʊ)
Target words (True words)	Low (a)		3 (e-a)	11 (I-a, Ʊ-a)
	Mid (e, o)	Nil		4 (I-e, Ʊ-e, I-o)
	High (I, Ʊ)	6 (a-I, a-Ʊ)	2 (e-I)	

Table 3

Number of Occurrence of Vowels Substituted with respect to Tongue Advancement in the True Words in order to prepare Nonword list

		Vowels Substituted w.r.t tongue advancement (Nonwords)		
		Front (I, e)	Central (a)	Back (Ʊ, o)
Target words (True words)	Front (I, e)		3 (a-I)	7 (Ʊ-I, Ʊ-e, o-e)
	Central (a)	9 (I-a, e-a)		5 (Ʊ-a)
	Back (Ʊ, o)	3 (I-Ʊ, I-o)	3 (a-Ʊ)	

b) Test for Articulation Judgment of Consonants

In this subtest, one consonant in each of the 33 true words was substituted by a different consonant to make another set of 33 nonwords. The phonotactic rules of Kannada language was considered while substituting the target consonant by another consonant (Rajapurohit, 1975; Hiremath, 1980). When consonants were substituted in the true words, the features of place, manner or voicing or a combination of these were used to form the nonwords. A difference of minimum of one to a maximum of three distinctive features was present between the true word and the corresponding nonword which were thus formed. For example, the consonant /t̪/ in the meaningful target word /tʃ^{h}ət̪rI/ (‘chatri’ meaning ‘umbrella’) was changed to /k/ resulting in a nonword /tʃ^{h}əkrI/ (chakri). In this case, there is only one feature difference between the target word and the substituted nonword in terms of place of articulation, i.e substitution of velar for dental. However, when the meaningful target word /nəkʃət̪ra/ (‘nakshatra’ meaning ‘star’) was changed to nonword /nəkʃədʒra/ (nakshajra), there is a difference of three features i .e /t̪/ differs from /dʒ/ in terms of place of articulation, manner of articulation and also voicing. The final list consisted of 66 stimuli including 33 true words with correct consonant forms and 33 nonwords with one consonant substitution. In the process, not all combinations of substitution patterns could be included to form the nonword list. The number of occurrence of the various substitutions made with respect to place, manner and voicing features are given in Tables 4, 5 and 6 respectively.

Table 4

Number of Occurrence of Consonants Substituted with respect to Place of Articulation in the True Words in order to prepare Nonword list

		Consonants substituted with respect to place of articulation (Nonwords)						
		Bilabial	Dental	Alveolar	Palatal	Retroflex	Velar	Glottal
Target words (True words)	Bilabial		2		1		3	
	Dental	1			1		3	
	Alveolar	4	1				2	1
	Palatal		1	1				
	Retroflex	1					1	
	Velar	1	3	2	1			
	Glottal							

Table 5

Number of Occurrence of Consonants Substituted with respect to Manner of Articulation in the True Words in order to prepare Nonword list

		Consonants substituted with respect to manner of articulation (Nonwords)						
		Stops	Fricatives	Affricates	Nasals	Continuant	Lateral	Flap
Target words (True words)	Stops		1	3	1		1	
	Fricatives	6						
	Affricates							
	Nasals							
	Continuant						1	
	Lateral					1		
	Flap	1	1					

Table 6

Number of Occurrence of Consonants Substituted with respect to Voicing in the True Words in order to prepare Nonword list

		Consonants substituted with respect to voicing (Nonwords)	
		Voiced	Unvoiced
Target words (True words)	Voiced		15
	Unvoiced	15	

The steps involved in the preparation of target stimuli for Articulation Judgment Test are summarized in Figure 1.

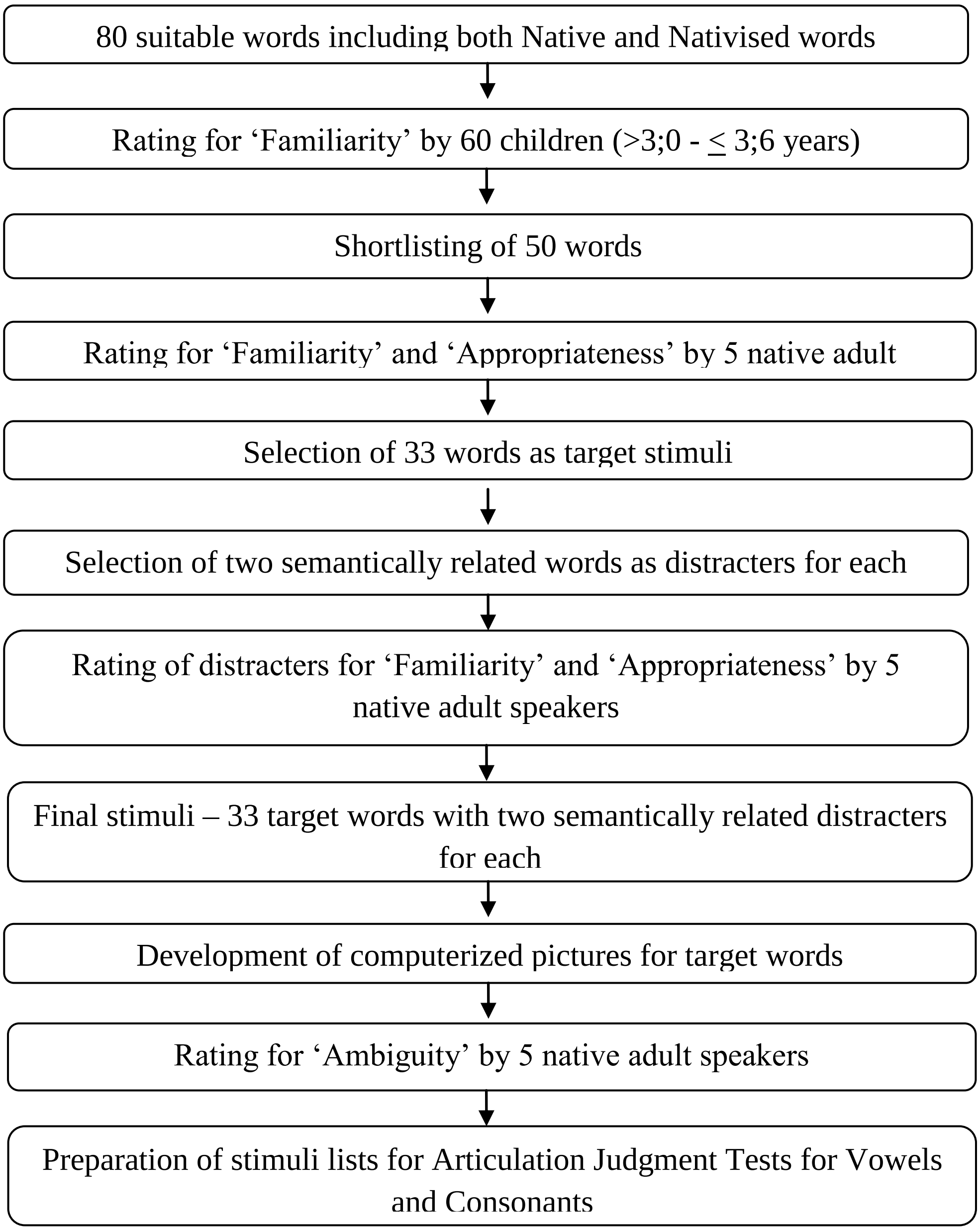


Figure 1. Flow chart depicting the steps involved in the preparation of target stimuli for Articulation Judgment Test.

Step 3: The two lists containing 66 stimuli each (in vowel and consonant test respectively) were audio recorded in a sound treated room where the ambient noise levels were within the permissible limits as per ANSI S3.1-1999 standard (Frank, 2000). The target stimuli were spoken by an adult female who was a fluent native speaker of Mysore dialect of Kannada language. A female voice was chosen assuming that there would be semblance to mother's voice of the participants and probably more soothing and comfortable to the participants. Also, female voice is reported to be more intelligible than male voice (Byrd, 1994; Kwon, 2010). The spoken stimuli were recorded using Computerized Speech Lab (Kay Elemetrics Corporation, New Jersey) software loaded on a desktop computer. A unidirectional microphone placed at a distance of 6 inches from the mouth was used to record the stimuli. The speaker was instructed to utter each stimulus three times as naturally as possible in a neutral tone. The recording was digitized at 44,100Hz sampling frequency and was stored in the computer. The recorded stimuli were played to 5 adult native speakers of Kannada language who were asked to listen to the three tokens of each stimulus (word or nonword) and select the best recording. The listeners were asked to ignore the changes made in the vowel or consonant, which could be reflected in the meaning of the words.

The best of the three tokens for each stimulus selected by the listeners were used to prepare the final list of stimuli. The two lists of final stimuli thus prepared were played to the same 5 adult Kannada speakers to check for clarity of the audio recorded stimuli. The listeners were asked to write down the word/nonword that they heard and the written responses of the listeners were analyzed. 100% match was obtained between the spoken targets and the written responses of all the listeners.

Normalization and randomization of the stimuli were done using custom scripts in MATLAB (MathWorks Inc. Natick, USA, R2010a). The rms amplitude of stimuli in the final lists was normalized to ensure equal intensity (-15dB) for each of the stimulus. Initially, the intensity of all the stimuli was measured and a correction factor was used to make the intensity of each stimulus equal ensuring that there is no loss of signal on either extremes of the intensity range. In order to minimize practice effects in the responses of participants, the items were randomized and six lists were prepared, three each for vowels and consonants. The stimuli were recorded with an inter stimulus interval of 4 seconds.

The steps involved in the audio recording of target stimuli for Articulation Judgment Test are summarized in Figure 2.

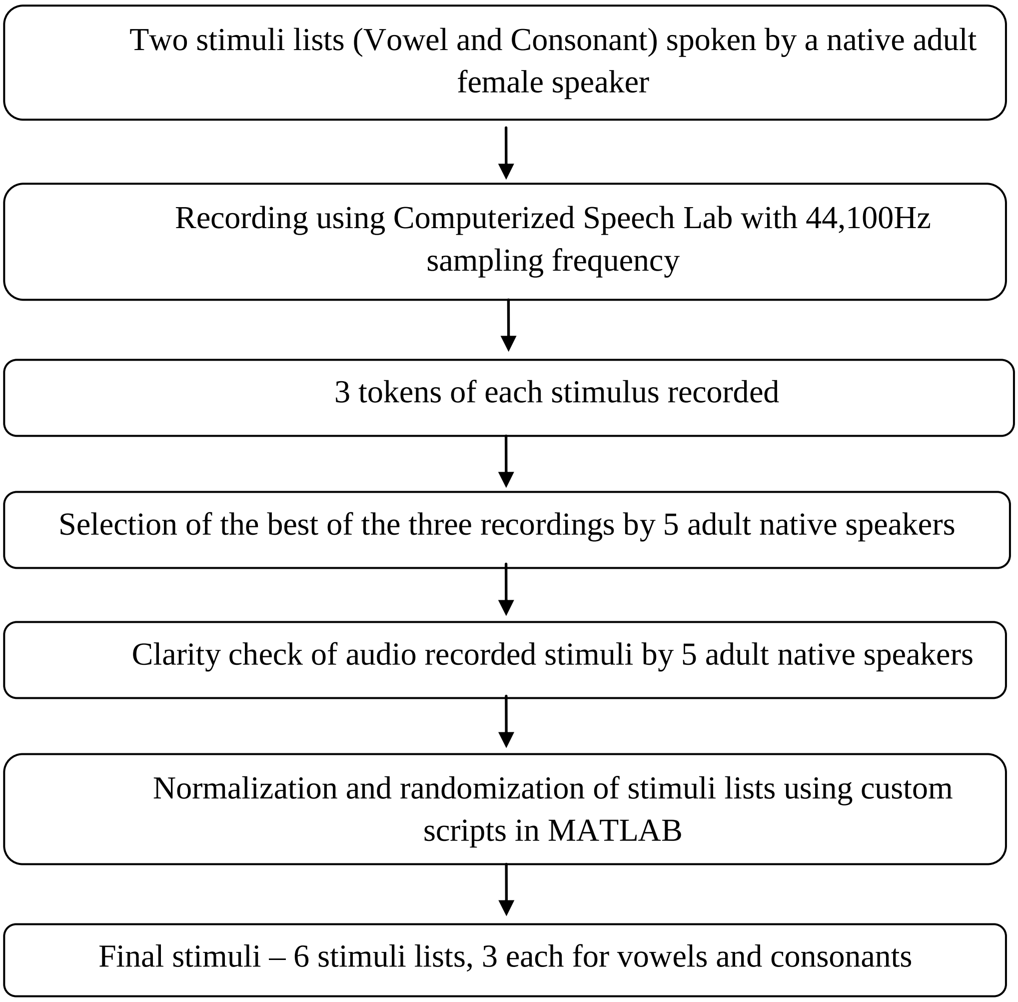


Figure 2. Flow chart depicting the steps involved in the audio recording of target stimuli for Articulation Judgment Test.

B. Articulation Correction test – a) Vowels and b) Consonants

Accuracy of children's productions of long, multisyllabic, phonologically complex words is reported to be a better measure of the precision of phonological representations, given that children are able to accurately produce a given consonant phoneme in the context of a short single word utterance before they can produce long, phonologically complex words (Fowler & Swainson, 2004; Swan & Goswami, 1997). The Articulation Correction test is an expressive measure reported to examine precision of phonological representations. The Articulation Correction test has been used as a measure of phonological representations by many investigators (E.g.: Anthony et al., 2010; Elbro, 1990; Elbro et al., 1998; Elbro & Petersen, 2004; Fowler & Swainson, 2004; Foy & Mann, 2001). In general, picture stimuli of multisyllabic words are presented to children and the pictures are named in a reduced form by deleting a number of phonemes from the actual target word. The children are then asked to name the pictures correctly.

The stimuli that were prepared for the Articulation Judgment Test were used as the stimuli for this section also. One set each of the randomized lists for vowels and consonants used in the Articulation Judgment Test was chosen as stimuli for the Articulation Correction Test for vowels and consonants respectively.

C. Sentence Imitation Test

Investigations have documented the role of phonological representations in immediate sentence recall (Anderson, 1971; Hayes-Roth & Hayes-Roth, 1977; Sachs, 1974; Park, 2002; Rummer & Engelkamp, 2001; Schweppe et al., 2011; Melby-Lervag & Hulme, 2010). A sentence imitation test provides an opportunity to analyze imitated utterances with reference to the corresponding target patterns. Sentence imitation is often a preferred choice of test for young children in a clinical setting considering the time constraints in collecting as well as analyzing spontaneous speech productions in this population. The stimuli for the Sentence Imitation Test in Kannada were developed in this study by the investigator in the following steps:

Step 1: Initially, 30 sentences were selected by the investigator for the test, considering the spoken vocabulary of preschool children to ensure that they were developmentally appropriate for children in the age range of 3 to 5 years. The mean length of utterances (MLU) for the sentences ranged from 4 to 7 morphemes. An attempt was also made to conform to the frequency of occurrence of phonemes in Kannada while constructing the sentences (Sreedevi, 2012). These sentences were given to 5 adult native speakers of Kannada language. They were asked to rate each sentence in the list for familiarity and appropriateness with respect to children in the age range of 3-5 years. A three-point rating scale was used to check for familiarity and this included: 1 = most familiar, 2 = familiar and 3 = not familiar. A two-point scale was used to check for appropriateness and this included: 1 = appropriate and 2 = inappropriate. The stimuli rated as 'most familiar' and 'appropriate' were chosen for the study and thus, a total of 20 sentences were included in the test as target stimuli.

Step 2: The 20 target sentences selected in step 1 were spoken by a native adult female speaker of Kannada and audio recorded using Computerized Speech Lab (Kay Elemetrics Corporation, New Jersey) software loaded on a desktop computer. The recording was carried out in a sound treated room with permissible limits of ambient noise levels as recommended by ANSI S3.1-1999 standard (Frank, 2000). The speaker was instructed to record each sentence three times as naturally as possible in a neutral tone using a unidirectional microphone placed at a distance of 6 inches from the mouth. The recording was digitized at a sampling frequency of 44,100Hz and stored in the computer.

The recorded tokens of each sentence were played to the same 5 adult native Kannada speakers. They were asked to listen to each token and select the best of the three recordings. The best token for each sentence was selected as the target stimuli. The target sentences were analyzed for various word shapes and syllable shapes. The number of occurrence of each of the word shape and syllable shape in the 20 target sentences is given in Table 7.

Table 7

Distribution of Word Shapes and Syllable Shapes in the Sentences Selected for Sentence Imitation Test

	Syllable structure	Number of occurrence	Percentage of occurrence
Word Shapes	Bisyllables	30	33.71
	Trisyllables	33	37.08
	Polysyllables	26	29.21
	• Four syllables	18	20.22
	• Five syllables	5	5.62
	• Six syllables	2	2.25
	• Seven syllables	1	1.12
	Total	89	-
Syllable shapes	V	10	2.55
	CV	218	79.27
	VC	7	3.64
	CVC	40	14.55
	Total	275	-

The steps involved in the preparation of target stimuli for Sentence Imitation test are summarized in Figure 3.

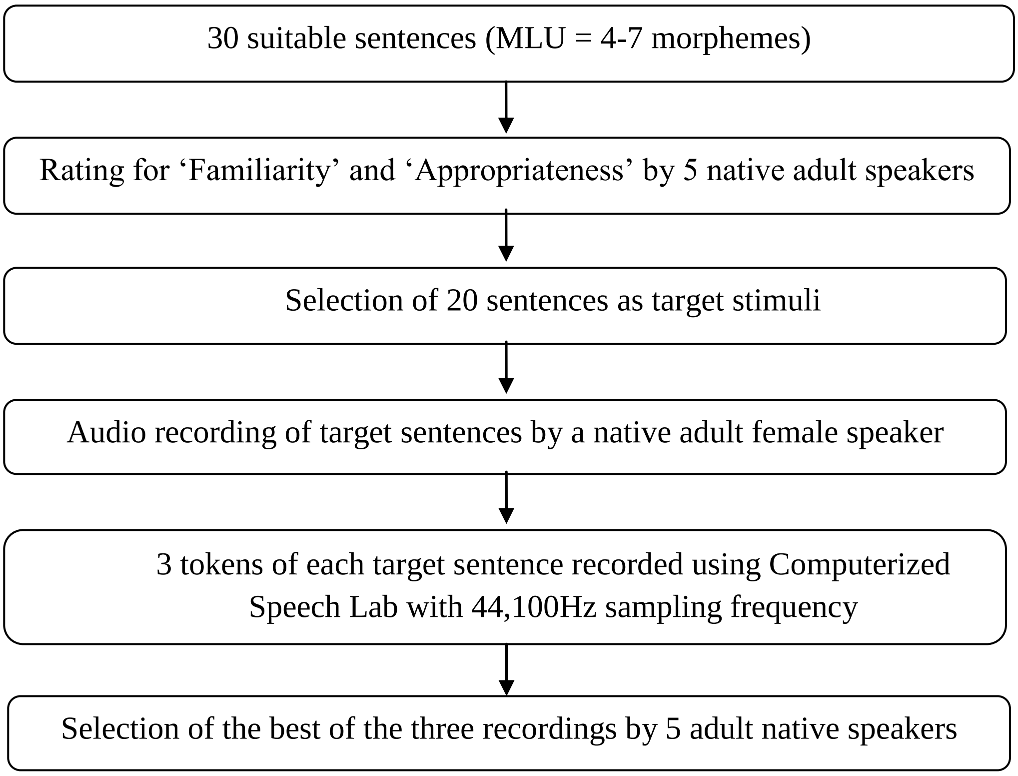


Figure 3. Flow chart depicting the steps involved in the preparation of target stimuli for Sentence Imitation test.

D. Rapid Automatized Naming Test - a) Nouns b) Verbs and c) Size

RAN tasks are considered as important measures of phonological processing in addition to that of phonological awareness and phonological short term memory. RAN is essentially a useful measure of phonological access as the task taps the ability to efficiently access or retrieve phonological representations from long term memory (Bowey et al., 2005; Kibby et al., 2014; Pennington et al., 2001; Ramus, 2014; Torgesen, et al., 1997; Vaessen et al, 2009; Vellutino et al., 2004; Wagner et al., 1997).

A list of 20 common nouns and verbs each in Kannada language was prepared by the investigator. The same 5 adult native speakers of Kannada who had rated the stimuli in the earlier sections of the test battery were asked to rate the stimuli for familiarity of the words to Kannada speaking children in the age range of 3 to 5 years. A three-point rating scale was used to check for familiarity and this included: 1 = most familiar, 2 = familiar and 3 = not familiar. Five nouns and five verbs that were rated as 'most familiar' were selected as the test stimuli. With respect to size, two sizes, 'small' and 'big' were considered as the target stimuli in the context of a 'ball'.

The target stimuli were represented in the form of computerized two dimensional pictures by a graphic designer. The pictures were presented to the same 5 adult native speakers of Kannada to rate for ambiguity of the pictures on a three-point scale as follows: 1 = least ambiguous, 2 = ambiguous and 3 = most ambiguous. Based on the rating, the pictures were modified until all the pictures were rated as 'least ambiguous' by the same 5 adults and then included as test stimuli. The pictures were arranged in an array of 50 items (5 rows * 10 columns), one each for nouns, verbs and size. Each of the stimulus arrays were printed on an A3 size sheet (11.5 x 16.5 inches) for good visibility to the participants of the study. The steps involved in the preparation of stimulus arrays for Rapid Automatized Naming tests are summarized in Figure 4.

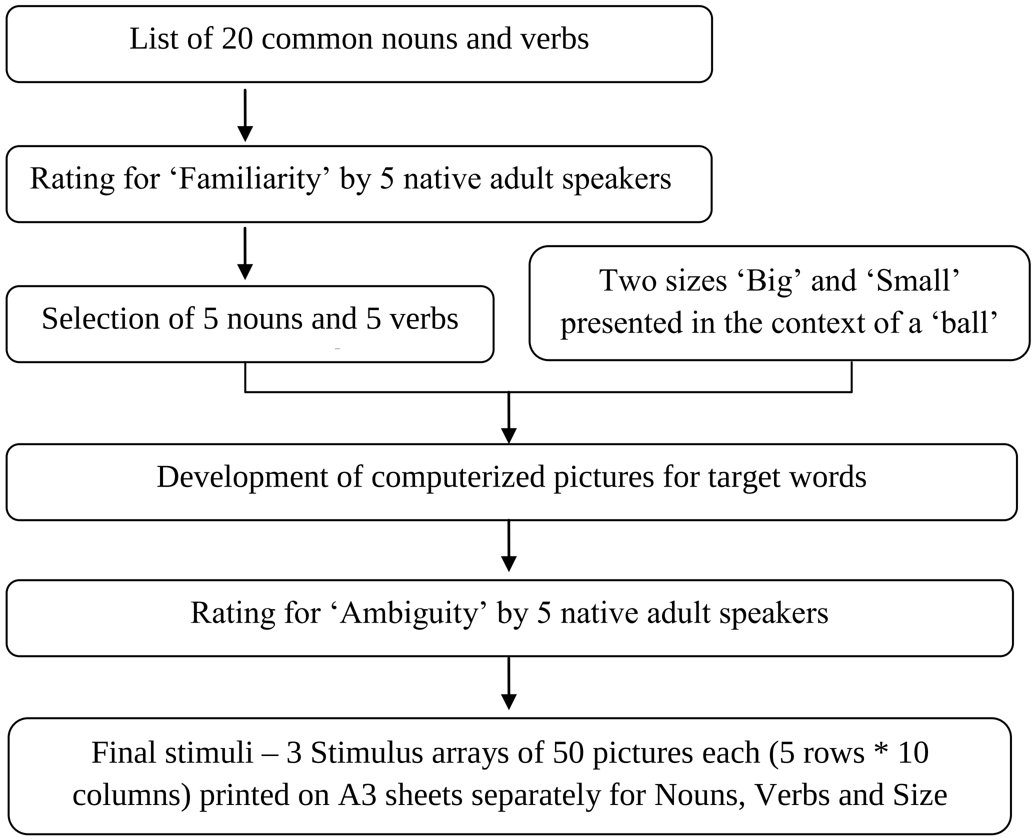


Figure 4. Flow chart depicting the steps involved in the preparation of stimulus arrays for Rapid Automatized Naming tests.

E. SHWA Test (Test for Knowledge of Orthographic Principles)

The SHWA test that was originally developed by Karanth and Prakash (1996) as a writing test to assess children's knowledge of phonemic-alphabetic principles of Kannada syllabary was used in this study. This test requires participants to combine visual symbols with imaginary, non-existent phonemes in Kannada in different vowel contexts and the participants are asked to write down the resulting grapheme based on their knowledge of Kannada orthography. The SHWA test was modified by Prema (1997) in the 'Test of Reading Acquisition Profile in Kannada (RAP-K)' to include both oral and written modalities and were presented with and without illustrations. In the test by Prema (1997), the stimuli set of five symbols and eight vowels were reduced to four imaginary phonemes that did not exist in the Kannada syllabary and five short vowels. The results of the study by Prema (1997) indicated that the SHWA test was acquired earlier in the oral mode compared to written mode. The nature of SHWA test administered in the oral mode by Prema (1997) could be considered as a measure of phonological representations as the task requires access to stored information on phonemes. RAP- K was standardized on Kannada speaking children between Grade III and Grade VII. In this study, as the participants were in the beginning stages of learning to write, only the oral mode of testing in SHWA test by Prema (1997) was considered. The oral mode of SHWA test (Prema, 1997) included 4 imaginary phonemes and 5 short vowels presented with illustrations.

Phase 2: Pilot Study

The pilot study was carried out to check for the appropriateness of the material developed. The test material developed in Phase 1 was administered on 24 typically developing Kannada speaking children between 3-5 years with six children each in age interval of six months (>3;0 - ≤3;6; >3;6 - ≤4;0; >4;0 - ≤4;6 and >4;6 - ≤5;0 years) which made up for 10% of the total participants considered for the study. The participants included in the pilot testing were different from the participants of the main study. The participants were selected randomly from schools and the testing was carried out in a quiet room in the school setting.

A. Articulation Judgment Test - a) Vowels and b) Consonants

Initially, the receptive picture vocabulary test was administered. Each of the 33 target stimuli was presented along with two semantically related distracters. The placement of the target picture and the distracters was randomized across stimuli in order to minimize chance responses. The participants were shown each picture plate at a time, consisting of the target picture and two distracters. They were instructed to point to the picture named by the investigator. When a participant failed to identify a given target, he/she was given practice sessions by the investigator until he/she correctly identified the target picture. During the practice sessions, the investigator modelled the names of the stimuli depicted in the picture and then presented the same for picture identification task in order to facilitate ease of administration of the other sections of the test battery where these targets were used as stimuli.

Articulation Judgment Test for Vowels and Consonants involved presentation of pictures along with audio recorded stimuli. The audio recorded stimuli were presented to the participants through headphones from a Compaq Laptop using Praat software (Boersma & Weenink, 2011). The corresponding picture stimuli were presented in the form of 5” * 7” cards. Participants were asked to judge if the spoken item matched with the name of the object depicted in the picture. Two practice trials were given to ensure that the participant understood the instructions and the method to respond. This was followed by the presentation of test stimuli for assessing articulation judgment for vowels and consonants. Three trials each were given for both vowels and consonants using the six randomized stimuli list. Both quantitative and qualitative analyses of the responses were carried out.

B. Articulation Correction test – a) Vowels b) Consonants

The procedure used to administer this test was the same as that of the Articulation Judgment Test for Vowels and Consonants. The difference was that Articulation Correction Test involved a two step procedure i.e. in addition to judging if the spoken stimulus matched the name of the object depicted in the picture, the participants were also instructed to correct the incorrect stimuli. Responses were recorded using a digital voice recorder (Sony digital voice recorder ICD –UX81F) and later transcribed verbatim using broad IPA. The transcribed responses were analyzed both with respect to perception and production.

C. Sentence Imitation Test

The audio recorded sentence stimuli were presented to the participants through headphones from a Compaq Laptop using Praat software (Boersma & Weenink, 2011). This was done to ensure good quality and consistency in the presentation of sentences to all participants. In few instances where participants refused to wear the headphones, sentences were presented through external speakers. Participants were instructed to repeat the individual sentences as it was heard. Two practice trials were given to ensure that they understood the instructions and once they understood, it was followed by presentation of test stimuli.

The responses of the participants were recorded using a digital voice recorder (Sony digital voice recorder ICD –UX81F) and were later transcribed verbatim using broad IPA. The transcribed sample was then analyzed to identify various word shapes and syllable shapes. This was followed by the computation of the percentage of each type of word shape and syllable shape for each participant using the formula

$$\frac{\text{Number of word shape (or syllable shape) produced}}{\text{Total number of words (or syllables) produced}} * 100$$

D. Rapid Automatized Naming – a) Nouns b) Verbs c) Size

The test stimuli were first presented for a naming task to ensure that the stimuli were familiar to the participants. The participants were then explained about the RAN task and were given practice trials prior to the administration of the test stimuli. The picture array used for the practice trial consisted of 12 items arranged in a matrix of 3 rows * 4 columns and the items used were different from the test stimuli. Once the participants were familiar with the test procedure, the test stimuli were administered. Each participant was shown the printed picture array and was instructed to name the items in a sequential manner as quickly and as accurately as possible. The time taken (in seconds) to name all items in the array was recorded separately for nouns, verbs and size as the respectively scored. In case of any errors, time taken for self-corrections, revision on request or prompting by the examiner was recorded in the performance duration.

E. SHWA Test (Test for Knowledge of Orthographic Principles)

Initially, the participants were given an illustartion of the task by presenting the new syllable formed by the combination of one of the imaginary phonemes with the vowel /a/. The participants were then presented with representative imaginary phonemes and were asked to combine the same with a given vowel to produce a new syllable. A score of '1' was given for every correct response and '0' for incorrect responses.

The results of the pilot study showed that:

a) The stimuli selected for various sections of the test battery were appropriate for Kannada speaking children in the age range of 3-5 years.

b) The instructions given were suitable for the participants to comprehend the nature of tasks and respond appropriately.

c) However, it was found that children in the age range of >3;0 - ≤3;6 years were unable to carry out the Articulation Judgment and Correction tasks. It was observed that either the participants perceived the tasks as difficult and denied to continue or the responses given were inconsistent and there were chance responses. Nevertheless, no change was made in the test in order to facilitate verification of the developmental trend.

d) None of the participants in the age range of 3 to 5 years were able to carry out the SHWA test.

Phase 3 – Modification of the test battery based on results of the pilot study

Based on the results of the pilot study, SHWA test was removed from the test battery as it was found to be inappropriate for the age group considered in the study. Details of stimuli for various subsections of the test battery, instructions, administration procedures and scoring are given in the Appendix 2. An overview of the test battery is given in Table 8.

Table 8

Overview of the Test Battery for Phonological Representations

S.N.	Tests	Stimuli	Task	Material	Scoring Pattern
1	*Receptive Picture Vocabulary Test (Control task)*	33 target stimuli with clusters presented along with two semantically related distracters for each stimulus.	Picture identification	Picture plates as given in Appendix 3	1 = correct identification 0 = incorrect identification
2.	*Articulation Judgment Test*				
	A. Vowels	66 stimuli (33 true words with no vowel change and 33 nonwords due to substitution of a vowel in the true word).	Judging the presented audio stimuli as correct or incorrect names of the object depicted in the picture.	a) Picture stimuli as given in Appendix 4. b) Audio recorded stimuli lists	*Quantitative analysis*: 1 = correct response 0 = incorrect response
	B. Consonants	66 stimuli (33 true words with no consonant change and 33 nonwords due to substitution of a consonant in the true word).			*Qualitative analysis*: Calculate number of occurrence of various error patterns on stimuli that were judged by participants as correct when the expected response was incorrect. *Vowels* - Analyze in terms of tongue height and tongue advancement *Consonants* - Analyze in terms of place of articulation, manner of articulation and voicing Refer to Appendix 5A and 5B for error analyses keys for vowels and consonants respectively.

3.	*Articulation Correction Test* *A. Vowels* *B. Consonants*	Same as the Articulation Judgment Tests	Judging the presented audio stimuli as correct or incorrect names of the object depicted in the picture and if incorrect, produce the correct form verbally	a) Picture books b) Audio recorded stimuli lists	*Overall Score:* 2 = judged correctly and production of target stimulus is accurate 1 = judged correctly, but production of target stimulus is inaccurate 0 = judged incorrectly / incorrect response *Production score*: 1 = Produced the manipulated vowel/consonant in the target stimuli accurately 0 = Did not produce the manipulated vowel/consonant in the target stimuli accurately
4.	*Sentence Imitation Test*	20 Kannada sentences	Verbal repetition	Audio recorded sentences	Record responses of the participants and transcribe verbatim using broad IPA. Calculate the number of occurrences of different word shapes and syllable shapes and the corresponding percentages.
5.	*Rapid Automatized Naming* *A. Nouns*	An array of 50 colored line drawings (5 rows * 10 columns) consisting of 10 repetitions of 5 common nouns	Naming each picture in the array, one after the other, in the order given as fast and as accurately as possible.	Arrays of colored line drawings as given in Appendix 6	Note the time (in seconds) taken to complete the task separately for nouns, verbs and size.

B. Verbs	An array of 50 colored line drawings (5 rows * 10 columns) consisting of 10 repetitions of 5 common verbs
C. Size	Two sizes, small and big were considered as the target stimuli in the context of a 'ball' randomly arranged in an array of 50 items (5 rows * 10 columns)

Phase 4- Administration and Standardization of the test battery on typically developing children

Participants

The test battery thus developed was administered on a total of 240 typically developing children in the age range of 3-5 years chosen randomly from English medium schools in the city of Mysore, Karnataka. They were further divided into four subgroups with an inter-age interval of six months (>3;0 - ≤3;6 years, >3;6 - ≤4;0 years, >4;0 - ≤4;6 years and >4;6 - ≤5;0 years). Each subgroup consisted of sixty participants with equal number of boys and girls. Participants were selected using random sampling technique. Details of the participants are given in Table 9.

Table 9

Details of Typically Developing Children who Participated in the Study

Sl. No.	Age range (in years)	N	Mean age (S.D)
1.	>3;0 - ≤3;6	60	3;3 (1.66)
2.	>3;6 - ≤4;0	60	3;9 (1.57)
3.	>4;0 - ≤4;6	60	4;3 (1.67)
4.	>4;6 - ≤5;0	60	4;9 (1.63)

Participant selection criteria

1. All the participants were native speakers of Kannada (a Dravidian language spoken in the state of Karnataka, India) and were brought up in an urban environment. The parents/caregivers of the participants spoke Kannada and English.
2. They were randomly selected from English medium schools that followed same education board (as prescribed by the state) and similar teaching methods.
3. The participants were chosen from the same geographical location i.e. within the city of Mysore, Karnataka.
4. They belonged to the middle socio-economic status as assessed by the revised NIMH Socio Economic Status Scale (Venkatesan, 2011).
5. Participants were screened using the WHO Ten Question Disability Screening Checklist (cited in Singhi et al., 2007) to rule out any structural, behavioral, emotional and sensory impairments.
6. Oral Peripheral Mechanism Examination was carried out for each participant through informal screening to ensure that he/she had structurally normal and functionally adequate oral mechanism.

7. The participants were assessed for age appropriate receptive and expressive language skills using the Assessment Checklist for Speech and Language skills (Swapna, Prema, & Geetha, 2010).

An informal interview with the parent/teacher was carried out to obtain additional information about the development of the participant. Participants with a history of delayed development, sensory issues, behavioral or neurological problems were excluded from the study.

Informed consent and ethical clearance

An informed consent was obtained from parents/caregivers/teachers of all the participants before including them in the study. The purpose and the procedures involved in the study were explained to the parents/caregivers/teachers of each participant and an informed written consent was obtained before including them in the study. The method followed in the study conformed to the ethical guidelines outlined by the ethical committee for bio-behavioral research involving human subjects at the All India Institute of Speech and Hearing (Basavaraj & Venkatesan, 2009).

Set up and administration of the test

The test was administered individually on all the participants by the investigator in a quiet environment in the school setting. It was ensured that the test room had proper seating arrangement and adequate illumination. The total time taken to test each participant was approximately 2.5 hours. The testing was carried out in 2-3 sessions within a span of one week depending on the comfort level of the participants. The order of administration of the various subsections of the test battery was randomized across subjects and across age groups to rule out order effect.

Phase 5 – Administration of the test battery on the clinical groups

In this phase, the test battery was administered on children with developmental disorders to check for the clinical utility of the test. The participants of the clinical group were subgrouped as follows:

1. Group 1 – Children with Speech Sound Disorder (SSD)
2. Group 2 – Children with Specific Language Impairment (SLI)
3. Group 3 – Children with Childhood Apraxia of Speech (CAS)
4. Group 4 – Children at risk for Dyslexia

The clinical diagnosis was made by a qualified Speech-Language Pathologist along with a team of Clinical Psychologist and Physio/Occupational therapist, wherever necessary using relevant clinical tools. Demographic details of participants in the clinical group are given in Table 10.

Participants in the clinical group were tested in a quiet environment in the clinical setting. The performance of participants in the clinical group was compared with that of typically developing participants to check for the clinical utility of the test battery developed. Participants in the clinical group were compared with typically developing groups matched for expressive language age. As the test battery included both receptive and expressive speech tasks, participants of the clinical group were included on the basis of their expressive language ages.

Table 10

Demographic Details of Participants in the Clinical Groups

Participant No.	Age (in years)	Gender	Clinical Diagnosis	Language Age (in months) RLA	ELA
1.	4;0	Girl	SSD	43-48	43-48
2.	4;11	Girl	SSD	55-60	49-54
3.	3;5	Girl	SSD	37-42	37-42
4.	4;1	Girl	SSD	49-54	43-48
5.	6;0	Boy	SSD	61-66	55-60
6.	5;0	Girl	SSD	55-60	55-60
7.	4;0	Girl	SSD	43-48	43-48
8.	3;6	Boy	SSD	37-42	37-42
9.	5;0	Boy	SSD	55-60	55-60
10.	5;0	Boy	SSD	55-60	55-60
11.	4;6	Boy	SSD	49-54	49-54
12.	6;0	Boy	SLI	55-60	49-54
13.	4;8	Boy	SLI	43-48	37-42
14.	7;0	Girl	SLI	61-66	55-60
15.	6;6	Boy	SLI	61-66	49-54
16.	4;9	Boy	SLI	49-54	43-48
17.	7;5	Boy	SLI	67-72	55-60
18.	5;10	Boy	SLI	49-54	49-54
19.	4;6	Boy	SLI	49-54	43-48
20.	4;8	Boy	SLI	49-54	43-48
21.	5;10	Boy	CAS	43-48	37-42
22.	6;0	Girl	CAS	55-60	43-48
23.	6;0	Boy	CAS	61-66	49-54
24.	6;0	Boy	ARD	67-72	55-60
25.	6;2	Girl	ARD	67-72	55-60
26.	5;3	Boy	ARD	55-60	49-54
27.	5;0	Boy	ARD	55-60	49-54
28.	6;0	Girl	ARD	67-72	55-60
29.	5;7	Boy	ARD	61-66	55-60
30.	5;9	Boy	ARD	67-72	55-60

Note: SSD = Speech Sound Disorder, SLI = Specific Language Impairment, CAS = Childhood Apraxia of Speech, ARD = At Risk for Dyslexia, RLA = Receptive Language Age, ELA = Expressive Language Age

All participants in the Clinical Group fulfilled the following common inclusionary criteria for the study.

a) All the participants were native speakers of Kannada residing in the same geographical location (Mysore city)

b) All participants belonged to the middle socio-economic status as assessed by the revised NIMH Socio Economic Status Scale (Venkatesan, 2011)
c) All participants had normal hearing acuity and normal or corrected vision
d) None of the participants had any oral structural deficits
e) The expressive language age of the participants was between 3-5 years of age with a mean length of utterance (MLU) of a minimum of three to four words as measured using the Assessment Checklist for Speech and Language Domain (Swapna et al., 2010)

The inclusion and exclusion criteria followed for selection of each Clinical subgroup were as follows:

1. ***Speech Sound Disorder (SSD)***

Inclusion criteria:

a) Children with the diagnosis of SSD were chosen from a clinical set up.
b) The diagnosis of SSD was carried out by Speech Language Pathologists on the basis of language assessment using the Assessment Checklist for Speech and Language Domain (Swapna et al., 2010) and performance on the Kannada Diagnostic Photo Articulation Test (Deepa & Savithri, 2010).
c) The diagnosis was cross verified with the diagnostic criteria for SSD specified by the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5) (American Psychiatric Association, 2013).
d) A qualitative analysis was also carried out by the investigator to verify for the presence of phonological processes persisting beyond the

expected developmental period and other idiosyncratic processes warranting the diagnosis of SSD.

Exclusion criteria:

- Participants with articulatory errors due to structural deficits (maxillofacial anomalies) or neurological disorders (e.g.: dysarthria) were excluded.
- Participants with co-morbid disorders such as hearing loss, receptive and expressive language deficits, Specific Language Impairment, Learning Disability, Attention Deficit (Hyperactivity) Disorder, developmental co-ordination disorders etc were also excluded.

2. *Specific Language Impairment (SLI)*

Inclusion criteria:

a) Children with SLI were identified from a clinical set up based on assessments made by Speech Language Pathologists and Clinical Psychologists.

b) The diagnosis of SLI was based on the criteria given by Leonard (1998) since there are no standardized tools available for the purpose in Kannada language. The receptive and expressive language levels were established based on restandardized Kannada Language Test (Shyamala, Vijayashree, & Jayaram, 2003).

Exclusion criteria:

- Participants with co-morbid disorders such as Hearing Loss, Autism Spectrum Disorders, Intellectual Disability, Motor Dysfunction, Learning Disability, Attention Deficit (Hyperactivity) Disorder, Developmental Co-ordination Disorders etc were excluded.

3. ***Childhood Apraxia of Speech (CAS)***

Inclusion criteria:

a. Children with CAS were identified from a clinical set up and included in the study.
b. The diagnosis of CAS was based on clinical observations and the tool developed by Banumathy (2009) in Kannada for identifying children with CAS.
c. This was also cross verified with the diagnostic features of CAS recommended by ASHA (2007).

Exclusion criteria:

- Participants with co-morbid disorders such as Dysarthria, Phonological Impairment, Stuttering, Spectrum Disorders, Intellectual Disability, Down Syndrome, Motor Dysfunction, Learning Disability, Attention Deficit (Hyperactivity) Disorder, Developmental Co-ordination Disorders etc were excluded.
- Participants with oral structural deficits and/or submucous cleft were excluded.

4. ***Children at risk for Dyslexia***

Inclusion criteria:

a. Participants were diagnosed as "at risk for dyslexia" based on assessments by qualified Speech Language Pathologists, Clinical Psychologists and Occupational therapist. Children were initially chosen from the clinical set up and schools based on the parental/teacher's report.

b. Participants were screened using Early Literacy Screening Tool (Shanbal, Goswami, Prathima, & Chaitra, 2010) and identified as "at risk for Dyslexia".

Exclusion criteria:

- Children with additional disabilities like ADHD, stuttering, misarticulation or any other neurological deficits were excluded.

Reliability measures

The administration of the test battery, response of the participants and also the response analyses are subjective in nature and hence, it is essential to establish reliability measures of the test battery. Both interjudge and intrajudge reliability was established using appropriate and suitable measures.

Interjudge reliability: Another qualified Speech Language Pathologist with five years of clinical experience served as the judge to establish interjudge reliability. She was first explained the objectives of the study and familiarized with the test protocol, administration procedures, scoring and analyses. The second investigator independently repeated the testing procedures on 10% of the participants in the typically developing group. Administration of the test battery was repeated on 6 participants selected randomly in each of the four age groups. The responses of participants were analyzed and compared with the corresponding scores obtained from analyses by the investigator using suitable statistical analysis to check for interjudge reliability.

Intrajudge reliability: The investigator repeated the administration of the test battery on 10% of the participants in the group of typically developing children. These participants (6 in each age group) were chosen randomly and the test battery was re-administered on them within two months of duration from the initial testing. The responses obtained from the participants on various sections of the test battery on the two occasions were compared and subjected to suitable statistical analysis to establish intrajudge reliability.

Analyses

The response of individual participants on various sections of the test battery was recorded in the Response Sheet given in Appendix 7. The responses of participants in the typically developing group on various subsections of the test battery was analysed and scored as described for each section. The raw scores thus obtained were compiled to obtain the data for each of the four age groups and two genders of typically developing participants. Similarly, raw scores for participants in the various clinical groups were compiled to obtain the data for each of the clinical groups on different subsections of the test battery.

The data obtained from the study was subjected to suitable statistical analyses using the Statistical Package for the Social Sciences (Version 21) (SPSS Inc, Chicago). Both parametric and non-parametric analyses were employed in the study including descriptive statistics, General Linear Model of Analysis of Variance and Mutivariate techniques. Descriptive statistics was carried out to estimate the mean, standard deviation and/or median for each of the parameters. The assumptions of parametric tests were verified using Shapiro-Wilk test of normality.

Repeated measures Analysis of Variance (Mixed ANOVA) was carried out to analyze the effect of age on Articulation Judgment Test, Articulation Correction Test and the Rapid Automatized Naming. Multivariate Analysis of Variance (MANOVA) was done to analyze the effect of age on each of the following: Articulation Judgment Test - Vowels, Articulation Judgment Test – Consonants, Articulation Correction Test – Vowels, Articulation Correction Test – Consonants, RAN – Nouns, RAN – Verbs and RAN – Size. Kruskal-Wallis H test was used to analyze the effect of age on Sentence Imitation test. Sign test for single samples was used to compare the percentages of various word shapes and syllable shapes obtained by the participants of each of the age groups with the corresponding targets.

Performance of participants in the clinical groups on various sections of the test battery was compared with that of the typically developing group using non-parametric measures. Kruskal Wallis H test was done to study the effect of group on the various tasks. Whenever significant differences were obtained, Mann-Whitney U test was used for pairwise comparisons. Wilcoxon Signed Rank Test was used to compare the scores obtained by participants in each of the clinical groups for vowels and consonants in the Articulation Judgment and Articulation Correction Tests. One-Sample Wilcoxon Signed Rank Test was used to compare the percentages of various word and syllable shapes obtained by the participants of each of the clinical groups with the corresponding targets in the Sentence Imitation test.

RESULTS

The study aimed to develop and standardize a test battery for the assessment of phonological representations in typically developing native speakers of Kannada in the age range of 3-5 years. Further, the test battery was administered on few children with developmental disorders to test for the clinical utility of the battery in assessing phonological representations.

Reliability measures

Both interjudge and intrajudge reliability measures were established for the administration of the tests in the battery on typically developing Kannada speaking children in the age range of 3 to 5 years. The results of inter and intra judge reliability are as follows:

Interjudge reliability: Cronbach's Alpha test was used to analyze the interjudge reliability between the investigator (judge 1) and another judge who was a qualified Speech Language Pathologist with five years of clinical experience, who independently administered the test battery on 10% (6 in each of the four age groups) of participants in the typically developing Kannada speaking children who were selected randomly. A good interjudge reliability was revealed with the Cronbach Alpha ranging from 0.80 to 0.97 for various tests in the battery.

Intrajudge reliability: Cronbach's Alpha test was used to analyze the intrajudge reliability between the scores obtained for various tests in the battery by the investigator when administered in the first instance and repeated on 10% (6 in each age group) of typically developing Kannada speaking children with a time gap of two months between the two assessments. Good intrajudge reliability was obtained with Cronbach's Alpha ranging from 0.80 to 0.96.

The results of the study are reported under the following heads:

I. Effect of gender on the performance of typically developing participants in various subsections of the test battery

II. Effect of age and stimuli on the performance of typically developing participants in various subsections of the test battery

III. Comparison of the performance of participants in the typically developing group and clinical group in various subsections of the test battery

I. Effect of Gender on the Performance of Typically Developing Participants in Various Subsections of the Test Battery

The results in this section address the first objective of the study i.e., to investigate and study the effect of gender on the performance of typically developing native speakers of Kannada in the age range of 3-5 years in various subsections of the test battery. Reliability of performance was tested by comparing scores across the three trials in each of the Articulation Judgment tests and RAN tests. The results of Cronbach's Alpha test are shown in Table 11. Good reliability was observed in both the tests in all the age groups and both genders. Hence, average of the scores of the three trials of Articulation Judgment tests and RAN tests were computed for each age group and gender and the averaged scores were subjected to further analyses.

Table 11

Results of Cronbach's Alpha Test for the Reliability across Three Trials of Articulation Judgment and RAN Tests in the Four Age Groups and Two Genders

Subsection	Age Group (in years)							
	>3;0 - ≤3;6		>3;6 - ≤4;0		>4;0 - ≤4;6		>4;6 - ≤5;0	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
AJ Vowels	-	-	0.905	0.790	0.809	0.858	0.828	0.886
AJ Consonants	-	-	0.855	0.739	0.819	0.829	0.837	0.858
RAN Nouns	0.932	0.932	0.943	0.909	0.953	0.946	0.939	0.961
RAN Verbs	0.775	0.780	0.953	0.935	0.984	0.942	0.926	0.884
RAN Size	0.919	0.948	0.948	0.949	0.911	0.939	0.955	0.955

Note: AJ = Articulation Judgment; RAN = Rapid Automatized Naming

The mean, standard deviation and median of the scores obtained by participants in the four age groups and both genders in various subsections of the test battery are presented in Table 12.

Table 12

Mean, Standard Deviation (SD) and Median of the Scores Obtained by the Participants in Various Subsections of the Test Battery

Subsection		Age Group (in years)							
		>3;0 - ≤3;6 (N=60)		>3;6 - ≤4;0 (N=60)		>4;0 - ≤4;6 (N=60)		>4;6 - ≤5;0 (N=60)	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Articulation Judgment Tests									
AJ Vowels	Mean	-	-	54.61	54.59	57.44	58.96	59.55	60.64
	SD	-	-	3.19	1.98	2.18	2.75	2.36	2.71
	Median	-	-	55.83	54.33	57.50	59.16	59.66	60.99
AJ Consonants	Mean	-	-	55.59	56.36	58.60	59.33	59.97	60.97
	SD	-	-	2.62	1.76	2.13	2.66	2.30	2.16
	Median	-	-	56.33	55.83	58.66	59.66	60.16	61.16
Articulation Correction Tests									
AC Vowels	Mean	-	-	109.71	110.70	114.83	117.00	120.96	122.26
	SD	-	-	9.13	9.33	7.50	7.21	5.93	4.94
	Median	-	-	111.50	111.00	115.50	119.00	121.00	124.00
AC Consonants	Mean	-	-	108.42	110.60	115.26	117.10	122.03	123.50
	SD	-	-	6.84	6.36	7.27	7.53	5.30	4.16
	Median	-	-	108.50	110.50	116.50	116.50	123.50	124.00
Sentence Imitation Test									
SI - Bisyllables	Mean	35.96	34.36	36.46	34.66	35.06	35.03	34.86	35.46
	SD	6.32	5.38	5.17	4.40	4.48	3.86	3.36	4.35
	Median	36.50	34.00	38.00	35.00	36.00	35.00	34.00	36.00

SI - Trisyllables	Mean	20.60	20.70	24.80	22.93	27.10	26.93	27.86	26.83
	SD	5.60	5.62	5.71	5.46	5.02	4.12	5.41	5.18
	Median	21.00	21.00	23.50	24.00	27.50	27.00	28.50	27.00
SI - Four Syllables	Mean	13.60	13.60	14.80	14.40	16.60	16.26	17.40	16.56
	SD	3.76	3.58	2.97	3.11	3.28	3.58	2.20	2.69
	Median	14.00	13.00	16.00	15.00	17.00	16.00	18.00	17.00
SI - Five Syllables	Mean	2.16	1.96	3.33	3.26	3.10	3.46	3.60	3.46
	SD	1.34	1.40	1.76	1.77	1.97	1.61	1.67	1.79
	Median	2.00	2.00	4.00	3.00	3.00	4.00	3.50	3.00
SI - Six Syllables	Mean	0.70	0.96	1.00	0.80	0.83	1.03	1.06	1.26
	SD	0.83	0.92	0.78	0.71	0.79	0.88	0.73	0.86
	Median	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SI - Seven Syllables	Mean	0.13	0.13	0.30	0.36	0.36	0.30	0.43	0.60
	SD	0.43	0.34	0.46	0.55	0.49	0.46	0.50	0.56
	Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
SI - Total Words	Mean	73.60	72.30	80.86	76.60	83.30	83.20	85.46	84.46
	SD	11.46	10.54	7.78	7.93	5.68	4.67	4.31	4.02
	Median	75.50	71.50	83.00	78.50	85.00	83.50	86.50	85.50
SI – VC	Mean	7.03	7.23	7.06	6.73	6.70	6.86	6.96	7.10
	SD	1.37	1.85	1.33	1.33	1.46	1.69	1.32	1.32
	Median	7.00	7.50	7.00	7.00	7.00	7.00	7.00	7.00
SI – CV	Mean	153.53	151.03	175.26	165.80	185.90	186.53	194.13	190.23
	SD	28.39	25.75	26.56	22.20	17.26	19.29	17.94	16.85
	Median	156.00	153.00	180.50	168.00	187.50	188.00	199.00	190.50
SI – V	Mean	10.20	10.16	11.26	10.26	10.63	10.93	10.76	10.96
	SD	1.90	1.93	2.21	1.87	2.17	1.68	1.54	1.12
	Median	10.50	10.00	11.00	10.00	11.00	11.00	11.00	11.00
SI – CVC	Mean	32.86	32.76	37.23	35.76	37.76	36.96	37.96	38.66
	SD	6.03	6.22	4.67	4.59	3.71	3.87	2.82	2.36
	Median	32.50	33.50	37.00	36.00	38.00	38.00	38.00	38.50
SI - Total Syllables	Mean	204.53	202.36	231.46	219.60	241.86	241.73	250.60	247.66
	SD	34.82	32.27	29.41	25.93	18.98	20.95	17.79	17.22
	Median	209.00	205.00	239.00	226.50	244.50	240.50	255.50	248.50
Rapid Automatized Naming Tests									
RAN Nouns	Mean	109.58	111.01	106.61	102.68	90.73	93.86	95.37	90.03
	SD	13.74	15.90	14.88	13.64	17.97	15.00	10.11	10.61
	Median	107.66	107.00	105.83	106.66	92.00	96.83	98.33	90.00
RAN Verbs	Mean	121.05	118.35	121.91	124.20	116.56	115.23	114.07	106.17
	SD	10.83	9.31	15.67	16.50	18.61	17.55	9.12	9.83
	Median	120.00	117.66	124.83	123.50	121.66	114.00	112.50	105.00
RAN Size	Mean	81.18	76.25	77.58	75.36	65.96	64.46	63.62	60.41
	SD	11.90	15.33	12.74	14.30	12.41	11.90	8.08	8.71
	Median	80.50	73.50	77.33	78.16	66.33	62.50	63.66	60.66

Note: RAN = Rapid Automatized Naming; AJ = Articulation Judgment; AC = Articulation Correction; SI = Sentence Imitation

The data was subjected to normality check in each age group and gender using Shapiro-Wilk's test of normality. In few of the subsections of the test, the data were found to be distributed non-normally ($p < 0.05$), and hence non-parametric tests were carried out. Mann-Whitney U test was administered for comparison of gender in each age group and each subsection. The results, presented in Table 13, revealed no significant difference between genders ($p > 0.05$) for any of the subsections in each of the four age groups. Thus, the data of the gender was combined for further analyses.

Table 13

Results of Mann-Whitney U Test Comparing Scores Between the Two Genders in Each of the Four Age Groups in Various Subsections of the Test Battery

Subsection		|Z|			
		>3;0 - ≤3;6	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
Articulation	Vowels	-	0.234	1.717	1.480
Judgment	Consonants	-	0.294	1.118	1.681
Articulation	Vowels	-	0.295	0.515	1.773
Correction	Consonants	-	0.210	0.268	0.173
Sentence	Total words	0.599	1.810	0.312	0.921
Imitation	Total syllables	0.281	1.805	0.030	0.717
Rapid	Nouns	0.022	0.577	0.806	1.942
Automatized	Verbs	1.095	0.414	0.325	1.847
Naming	Size	1.737	0.769	0.288	1.472

*Note: * - p < 0.05*

II. Effect of Age and Stimuli on the Performance of Typically Developing Participants in Various Subsections of the Test Battery

The results reported in this section address the second and third objective of the study i.e., to investigate and study the effect of age and stimuli on the performance of typically developing native speakers of Kannada in the age range of 3-5 years in various subsections of the test battery. The results are reported separately for each subsection of the test battery.

1. Effect of Age and Stimuli on the Scores of Articulation Judgment Test

Prior to the administration of the Articulation Judgment Test, Receptive Picture Vocabulary Test was administered to ensure familiarity of the stimuli used in the Articulation Judgment Test. The mean and standard deviation of scores obtained in the Receptive Picture Vocabulary Test are presented in Table 14. The maximum possible score was 33 and hence an apparent ceiling effect is evident in the scores. These results indicate that the target words used as stimuli in the Articulation Judgment Test were within the receptive vocabulary of the participants.

Table 14

Mean and Standard Deviation (SD) of the Scores Obtained by the Participants in the Receptive Picture Vocabulary Test

Age Group (in years)	Mean	SD
>3;0 - ≤3;6	32.55	0.74
>3;6 - ≤4;0	32.30	0.88
>4;0 - ≤4;6	32.41	0.80
>4;6 - ≤5;0	32.80	0.48

Note: Maximum score = 33

On administering the Articulation Judgment Test for vowels and consonants, it was observed that participants in the age group of >3;0 - ≤3;6 years were unable to perform the task. They either failed to understand the instructions of the test or refused to do the task as they perceived it to be difficult. Further, of the total 60 participants in the age range of >3;6 - ≤4;0 years, only 24 were able to complete these tests and hence the data is presented for 24 participants in this age group. However, all 60 participants in the age range of >4;0 - ≤4;6 years and >4;6 - ≤5;0 years could perform the Articulation Judgment Test for both vowels and consonants.

Cronbach's Alpha test used to check reliability across the three trials of Articulation Judgment Test revealed good reliability for both vowels and consonants in each of the three age groups (Cronbach's Alpha = 0.878, 0.843, 0.853 for vowels; and 0.757, 0.826, 0.843 for consonants in the age groups >3;6 - ≤4;0, >4;0 - ≤4;6 and >4;6 - ≤5;0 years respectively). Therefore, scores in the three trials each of the Articulation Judgment Test for vowels and consonants were averaged and the averaged scores were subjected to further analyses. The mean, standard deviation and median of the averaged scores for vowels and consonants are presented in Table 15.

Table 15

Mean, Standard Deviation (SD) and Median of the Average Scores Obtained by the Participants in the Articulation Judgment Test for Vowels and Consonants

Age Group	N	Vowels			Consonants		
(in years)		Mean	SD	Median	Mean	SD	Median
>3;6 - ≤4;0	24	54.61	2.70	55.16	55.91	2.29	56.33
>4;0 - ≤4;6	60	58.20	2.58	58.16	58.96	2.42	59.00
>4;6 - ≤5;0	60	60.09	2.58	60.33	60.47	2.27	60.50

Note: Maximum score = 66

It is observed that the mean scores increased with increasing age for both vowels and consonants. Further, the mean scores obtained for the articulation judgment for consonants was slightly higher than that of vowels in all the age groups. The data was tested for normal distribution using Shapiro Wilk's test of normality. The results revealed that the scores for both vowels and consonants were distributed normally ($p > 0.05$) in all three age groups. Sphericity was assumed ($p > 0.05$) based on the results of Mauchly's test of Sphericity.

Subsequently, repeated measures ANOVA with age as between-subject factor (Mixed ANOVA) was carried out to test the effect of stimuli on the scores of Articulation

Judgment Test. Results revealed significant main effect of age [$F(2, 141) = 38.162$, $p < 0.001$, partial $\eta^2 = 0.351$] and stimuli [$F(1, 141) = 46.886$, $p < 0.001$, partial $\eta^2 = 0.250$]. The interaction between age and stimuli was also found to be significant [$F(2, 141) = 4.486$, $p < 0.05$, partial $\eta^2 = 0.060$]. Post Hoc analysis using Tukey's multiple comparisons showed that there were significant differences ($p < 0.05$) across all three age groups.

As there was a significant interaction between age and stimuli, further analysis using one-way MANOVA was carried out to analyze the effect of age on the scores obtained in the Articulation Judgment Test for vowels and consonants. Results of one-way MANOVA revealed significant main effect of age [$F(4, 280) = 17.216$, $p < 0.01$, Wilk's $\Lambda = 0.644$, partial $\eta^2 = 0.197$]. Subsequent analysis using Univariate ANOVAs revealed a significant effect of age on scores of Articulation Judgment Test for both vowels [$F(2, 141) = 38.375$, $p < 0.01$, partial $\eta^2 = 0.352$] and consonants [$F(2, 141) = 32.675$, $p < 0.01$, partial $\eta^2 = 0.317$]. Post Hoc analysis using Tukey's multiple comparisons showed significant differences ($p < 0.05$) across all three age groups for both vowels and consonants.

Paired t test was run to compare between the scores of vowels and consonants within each age group. The results showed a significant difference between vowels and consonants in all the three age groups [>3;6 - $\leq$4;0 years ($t(23) = 4.685$, $p < 0.001$), >4;0 - $\leq$4;6 years ($t(59) = 4.660$, $p < 0.001$) and >4;6 - $\leq$5;0 years ($t(59) = 2.222$, $p < 0.05$)]. The lesser significance observed in the age group of >4;6 - $\leq$5;0 years could have accounted for the significant interaction effects.

Considering that the sample sizes across age groups were unequal, the data was also tested using non parametric tests. As in parametric tests, the results of Kruskal Wallis H test revealed significant effect of age on scores of Articulation Judgment Test for both vowels [$\chi^2(2) = 46.108$, $p < 0.01$] and consonants [$\chi^2(2) = 42.948$, $p < 0.01$]. Pairwise comparisons using Mann-Whitney U test showed a significant difference ($p < 0.05$) across the three age groups for both vowels and consonants.

In summary, the Articulation Judgment Test could be carried out by typically developing children only beyond the age of 3;6 years. A significant effect of age was observed on the scores of participants in the Articulation Judgment Test for both vowels and consonants. Participants in the higher age groups obtained higher scores on the test compared to the lower age groups for both vowels and consonants. A significant effect of stimuli was also observed, with participants in each of the three age groups obtaining higher scores in the Articulation Judgment Test for consonants compared to that of vowels.

2. Effect of Age and Stimuli on the Error Patterns in the Articulation Judgment Test

Qualitative analyses of the error responses in the Articulation Judgment Test were carried out in order to understand the nature of errors in the perspective of development of phonological representations for vowels and consonants in typically developing children. The error patterns were analyzed in terms of tongue height and tongue advancement for vowels and in terms of place of articulation, manner of articulation and voicing for consonants. The number of occurrence of various error patterns on stimuli that were judged by participants as correct when the expected response was incorrect was calculated. For example, when a word /səmƱd̪ra/ was presented as /səmId̪ra/ (target stimulus involves substitution of front vowel /I/ for back vowel /Ʊ/ with respect to tongue advancement), the child was expected to judge the stimuli as incorrect. On the contrary, if the child judged the presented stimuli as correct, it was considered as one instance of error with respect to tongue advancement, specifically substitution of front vowel for back vowel. Similarly, every error response of the participants on incorrect stimuli was analyzed with respect to the above mentioned features of vowels and consonants. The error patterns for Articulation Judgment Test for vowels and consonants are reported under two heads as follows.

A. Error patterns in Articulation Judgment Test for Vowels

The number of occurrence of individual error patterns in the three trials of the Articulation Judgment Test for Vowels was calculated along with the total opportunities available for a particular error pattern. This was initially done for individual participants followed by the computation of total number of occurrences of each error pattern and the total number of opportunities for each group of participants. These were expressed in percentages separately for tongue height and tongue advancement and the same is shown in Tables 16 and 17 and, Figures 5 and 6 (as radar charts[3]) respectively.

[3] A radar chart is a two-dimensional plot of a sequence of equi-angular spokes called radii. Each spoke represents a separate variable and the data length of a spoke is proportional to the magnitude of the variable for the data point relative to the maximum magnitude of the variable across all data points. This graphical method is suitable in plotting three or more quantitative variables represented on axes with common starting points. The relative position and angle of the axes is typically uninformative.

Table 16

Percentage of Error Patterns in Terms of Tongue Height in the Participants for the Articulation Judgment Test for Vowels

Error pattern			Age Group (in years)		
Target	Substitution	Pattern	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
Low (L)	Mid (M)	M-L	58	44	34
High (H)	Mid (M)	M-H	33	21	23
High (H)	Low (L)	L-H	33	22	15
Low (L)	High (H)	H-L	24	18	12
Mid (M)	High (H)	H-M	9	6	6

Table 17

Percentage of Error Patterns in Terms of Tongue Advancement in the Participants for the Articulation Judgment Test for Vowels

Error pattern			Age Group (in years)		
Target	Substitution	Pattern	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
Central (C)	Front (F)	F-C	36	29	21
Back (B)	Central (C)	C-B	37	27	19
Front (F)	Central (C)	C-F	30	17	11
Central (C)	Back (B)	B-C	21	13	9
Back (B)	Front (F)	F-B	20	14	12
Front (F)	Back (B)	B-F	12	8	8

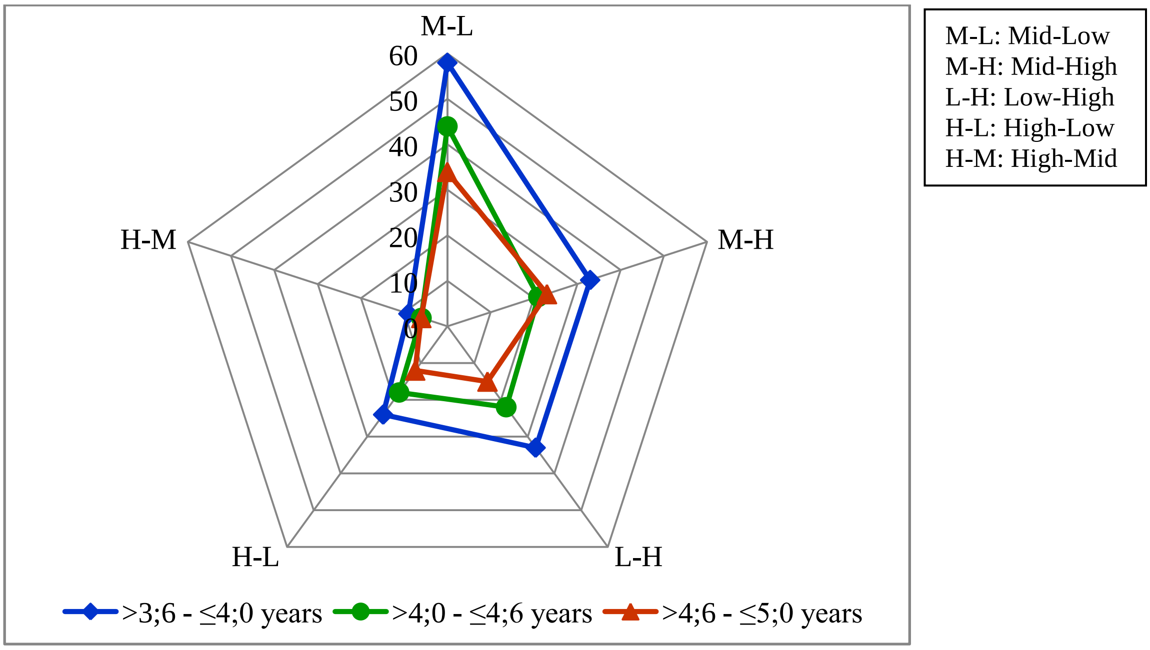


Figure 5. Percentage of Error Patterns in Terms of Tongue Height in the Articulation Judgment Test for Vowels.

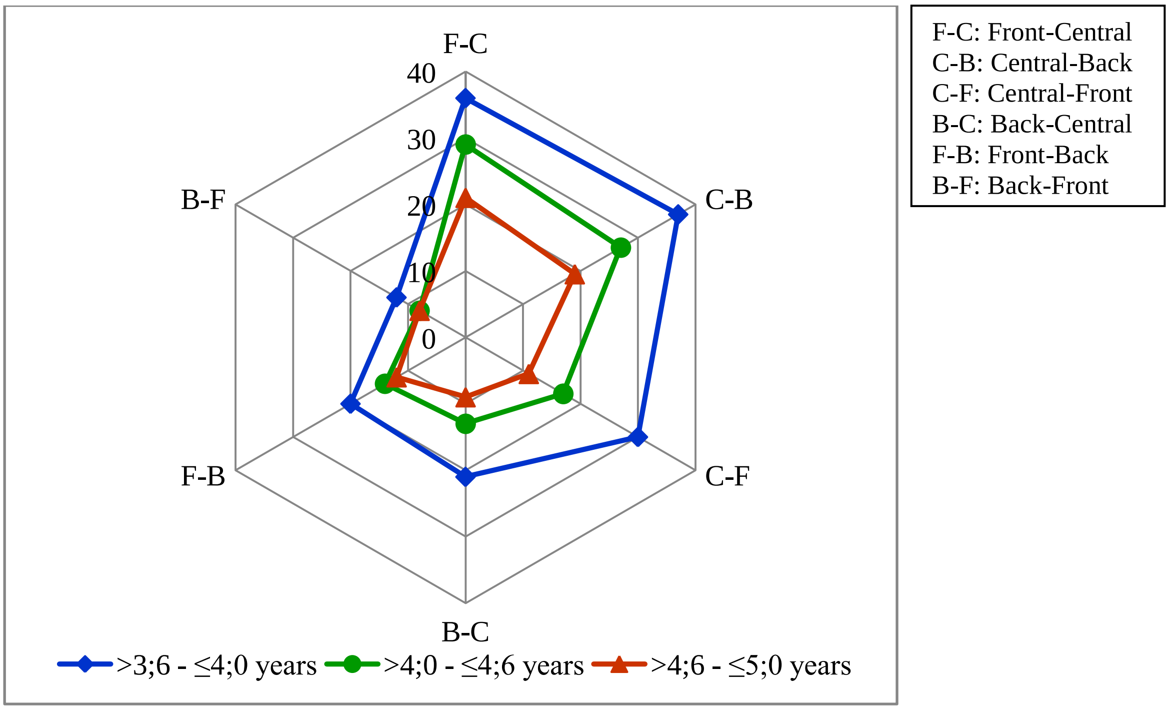


Figure 6. Percentage of Error Patterns in Terms of Tongue Advancement in the Articulation Judgment Test for Vowels.

The percentage of various error patterns for vowels decreased with increase in age both in terms of tongue height and tongue advancement. Children in the age group of >3;6 - ≤4;0 years exhibited greater percentage of errors compared to those in the age group of >4;0 - ≤4;6 years who in turn had greater errors than those in the >4;6 - ≤5;0 years group. Overlap in the percentage of certain error patterns was observed between participants in the age group of >4;0 - ≤4;6 years and >4;6 - ≤5;0 years whereas those in the >3;6 - ≤4;0 years age group showed different patterns when compared to the other age groups. With respect to tongue height, the percentage of errors was highest when the substitution involved a mid vowel for a target high or low vowel followed by substitution of low vowels for high vowels. The errors were minimum when a target vowel (mid/low) was substituted by a high vowel. In general, it is observed that the error patterns decreased as the tongue height of substituted vowels varied from low or mid to high. This was found in each of the age groups studied.

With respect to error patterns in tongue advancement, the percentage of errors decreased as the placement of the tongue for the substituted vowels varied from front to back. Maximum errors were observed when a front vowel was substituted for a central vowel followed by substitution of central vowel for back and front vowels respectively. The errors were minimal when a back vowel was substituted for a front vowel. In general, it is observed that the error percentage decreased with increase in distance between the target and substituted vowels with respect to tongue advancement.

B. Error patterns in Articulation Judgment Test for Consonants

The number of occurrence of individual error patterns in the three trials of the Articulation Judgment Test for Consonants was calculated along with the total opportunities available for a particular error pattern. This was initially done for individual participants followed by the computation of total number of occurrences of each error pattern and the total number of opportunities for each group of participants. The error patterns were expressed in percentages separately for the features of place of articulation, manner of articulation and voicing and the results are presented in Tables 18, 19 and 20 and Figures 7, 8 and 9 respectively.

Table 18

Percentage of Error Patterns in Terms of Place of Articulation in the Participants on Articulation Judgment Test for Consonants

Error pattern			Age Group (in years)		
Target	Substitution	Pattern	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
Dental (D)	Palatal (P)	P-D	50	33	35
Velar (V)	Dental (D)	D-V	40	33	24
Alveolar (A)	Velar (V)	V-A	39	28	27
Dental (D)	Bilabial (B)	B-D	33	26	26
Bilabial (B)	Dental (D)	D-B	31	22	14
Dental (D)	Velar (V)	V-D	28	20	14
Velar (V)	Bilabial (B)	B-V	25	10	7
Palatal (P)	Alveolar (A)	A-P	22	11	15
Alveolar (A)	Glottal (G)	G-A	19	12	8
Alveolar (A)	Bilabial (B)	B-A	16	10	9
Velar (V)	Palatal (P)	P-V	15	7	5
Palatal (P)	Dental (D)	D-P	13	4	3
Bilabial (B)	Palatal (P)	P-B	8	8	6
Bilabial (B)	Velar (V)	V-B	7	6	4
Retroflex (R)	Velar (V)	V-R	4	0	2
Retroflex (R)	Bilabial (B)	B-R	3	0	2
Velar (V)	Alveolar (A)	A-V	1	3	2
Alveolar (A)	Dental (D)	D-A	1	1	1

Table 19

Percentage of Error Patterns in Terms of Manner of Articulation in the Participants on Articulation Judgment Test for Consonants

Error pattern			Age Group (in years)		
Target	Substitution	Pattern	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
Flap (Fl)	Stops (S)	S-Fl	60	34	35
Stops (S)	Nasals (N)	N-S	46	31	22
Stops (S)	Affricates	A-S	25	16	15
Continuant (C)	Lateral (L)	L-C	22	10	15
Flap (Fl)	Fricatives (F)	F-Fl	19	12	8
Fricatives (F)	Stops (S)	S-F	16	10	10
Lateral (L)	Continuant (C)	C-L	3	0	1
Stops (S)	Fricatives (F)	F-S	1	3	3
Stops (S)	Lateral (L)	L-S	1	3	2

Table 20

Percentage of Error Patterns in Terms of Voicing in the Participants on Articulation Judgment Test for Consonants

Error pattern			Age Group (in years)		
Target	Substitution	Pattern	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
Voiced (V)	Unvoiced (UV)	UV-V	33	26	22
Unvoiced (UV)	Voiced (V)	V-UV	13	9	9

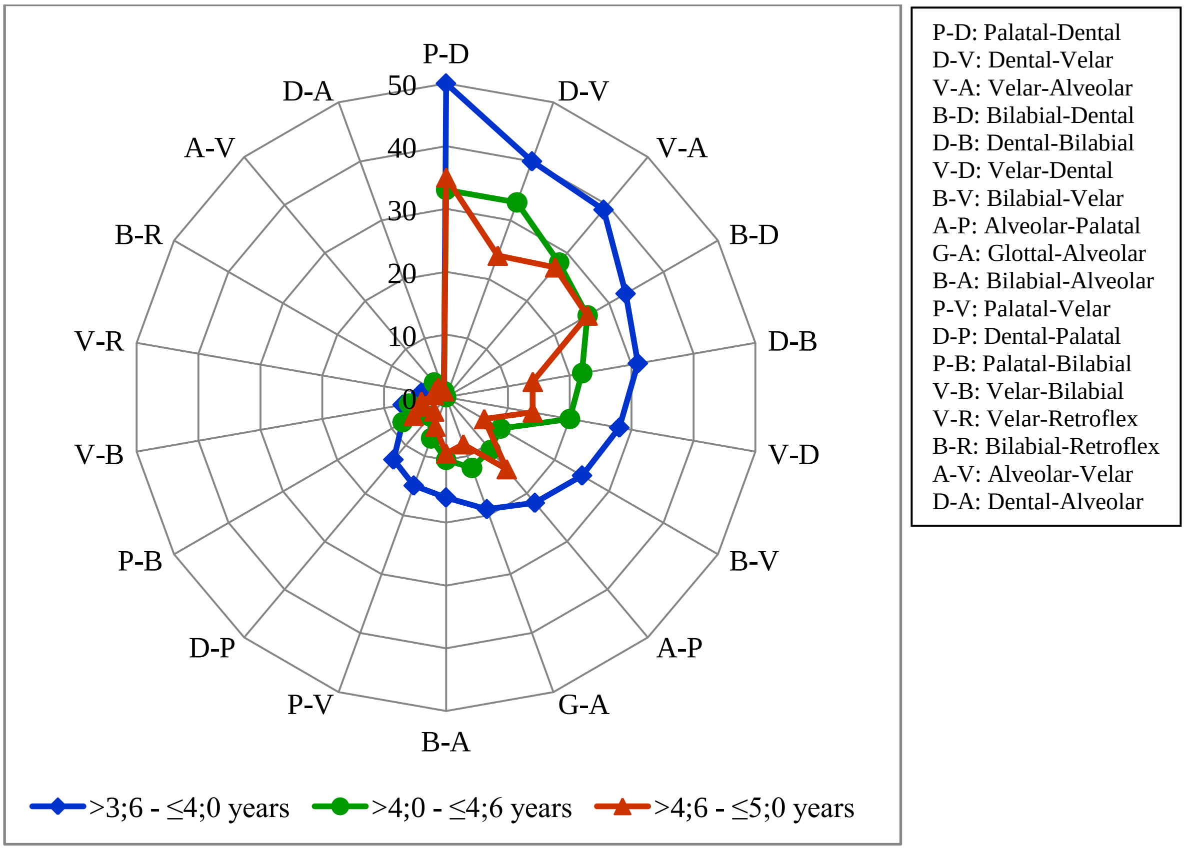
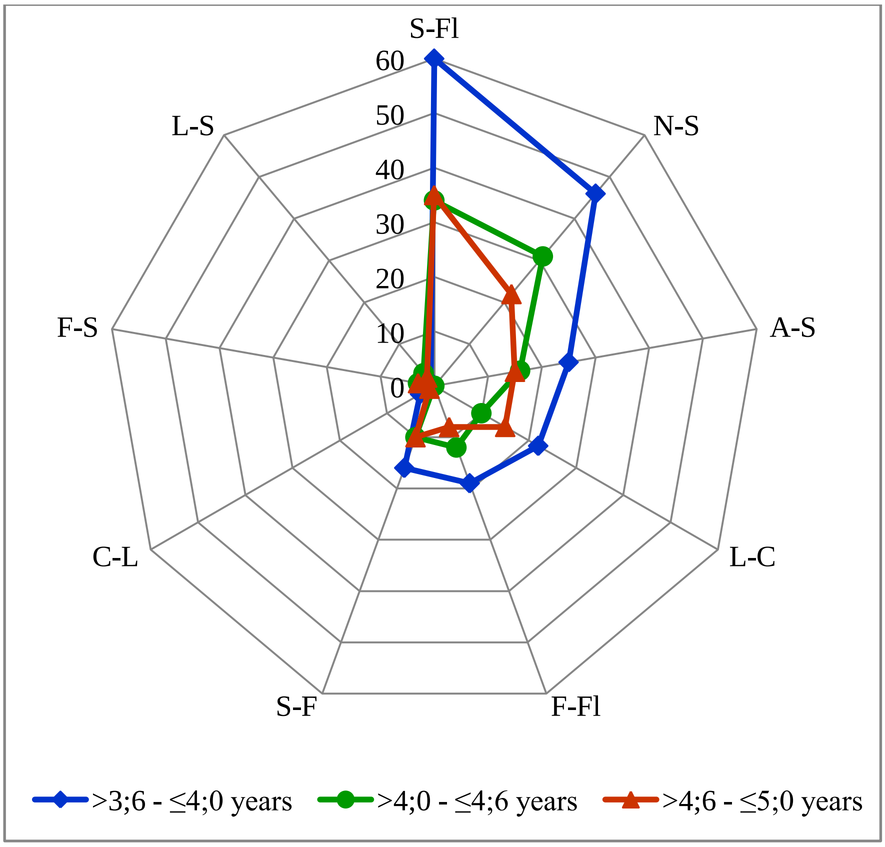
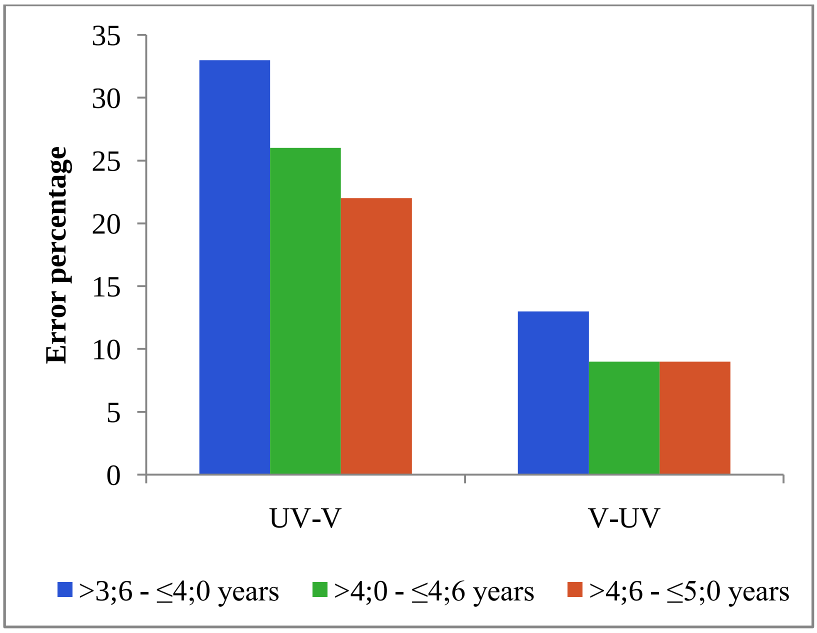


Figure 7. Percentage of Error Patterns in Terms of Place of Articulation in the Articulation Judgment Test for Consonants.



S-Fl: Stop-Flap
N-S: Nasals-Stops
A-S: Affricates-Stops
L-C: Laterals-Continuants
F-Fl: Fricatives-Flap
S-F: Stops-Fricatives
C-L: Continuants-Laterals
F-S: Fricatives-Stops
L-S: Laterals-Stops

Figure 8. Percentage of Error Patterns in Terms of Manner of Articulation in the Articulation Judgment Test for Consonants.



UV-V: Unvoiced-Voiced
V-UV: Voiced-Unvoiced

Figure 9. Percentage of Error Patterns in Terms of Voicing in the Articulation Judgment Test for Consonants.

Similar to that of the vowels, it is evident from Figures 7, 8 and 9 that the percentage of various error patterns for consonants decreased with increase in age in terms of place of articulation, manner of articulation and voicing. While participants in the age range of >3;6 - ≤4;0 years were clearly distinguishable from the other groups for most of the error patterns, overlap in the percentage of certain error patterns was evident in the age groups of >4;0 - ≤4;6 years and >4;6 - ≤5;0 years.

The maximum percentage of errors, with respect to place of articulation, was observed when palatal sounds were substituted for dental sounds whereas it was least for substitution of dental for alveolar sounds. The percentages of error patterns did not exhibit any particular trend with respect to change in the place of articulation. There was no evidence to infer that the error patterns increased as the place of articulation moved from front part of the oral cavity to the back or vice versa. For instance, the percentage of errors observed for substitution of dental sounds for velar sounds and the substitution of velar for alveolar sounds were approximately similar.

Substitution of stop for flap yielded the highest error percentage in terms of manner of articulation followed by substitution of nasals for stops and affricates for stops. The minimum percentage of error was observed when laterals were substituted by stops. Similar to the place of articulation, no particular trend was observed in the data from the perspective of manner of articulation. In terms of voicing, substitution of unvoiced for voiced consonants had greater error percentage compared to vice versa in participants of all three age groups.

Thus, analyses of error patterns in the responses of participants on the Articulation Judgment Test for vowels and consonants clearly indicated that the percentages of various error patterns reduced with increase in age. Error percentages were distinct for participants in the age group of >3;6 - ≤4;0 years whereas, overlap in the percentage of some of the error patterns was observed between those in the age group of >4;0 - ≤4;6 years and >4;6 - ≤5;0 years. This was found to be true for both vowels and consonants. With respect to vowels, errors decreased as the tongue height of substituted vowels increased from low/mid to high or when the tongue placement for the substituted vowel moved from front to back.

On the other hand, no particular trend could be discerned for errors along the dimensions of place and manner of articulation for consonants. Errors were maximally observed when place of articulation was changed from palatal to dental and when manner of articulation varied from flap to stops. Considering the voicing feature, substitution of unvoiced consonants for voiced consonants yielded higher error percentages.

3. Effect of Age and Stimuli on the Scores of Articulation Correction Test

Similar to the Articulation Judgment Test, participants in the age range of >3;0 - ≤3;6 years were unable to perform the Articulation Correction Test for vowels as well as consonants. Twenty four participants in the age group of >3;6 - ≤4;0 years and sixty participants each in the age ranges of >4;0 - ≤4;6 years and >4;6 - ≤5;0 years were able to complete the test. The mean, standard deviation and median of the scores obtained in the Articulation Correction Test for vowels and consonants are given in Table 21.

Table 21

Mean, Standard Deviation (SD) and Median of the Total Scores Obtained by the participants in the Articulation Correction Test for Vowels and Consonants

Age Group (in years)	N	Vowels			Consonants		
		Mean	SD	Median	Mean	SD	Median
>3;6 - ≤4;0	24	110.12	9.02	111.50	109.33	6.59	109.50
>4;0 - ≤4;6	60	115.90	7.38	117.00	116.18	7.40	116.50
>4;6 - ≤5;0	60	121.61	5.45	122.00	122.76	4.78	123.50

Note: Maximum Score = 132

The mean scores of Articulation Correction Test for both vowels and consonants increased with increase in age. The mean scores for vowels and consonants were similar in each of the three age groups. The data was tested for normal distribution using Shapiro Wilk's test of normality. The results revealed that the scores for both vowels and consonants were distributed normally ($p > 0.05$) in all three age groups. Sphericity was assumed ($p > 0.05$) based on the results of Mauchly's test of Sphericity.

Repeated measures ANOVA with age as between-subject factor (Mixed ANOVA) was carried out to test the effect of stimuli on scores obtained in the Articulation Correction Test. Results revealed significant main effect of age [$F(2, 141) = 38.797$, $p < 0.01$, partial $\eta^2 = 0.355$] but not stimuli [$F(1, 141) = 0.193$, $p > 0.05$, partial $\eta^2 = 0.001$]. There was no significant interaction between age and stimuli [$F(2, 141) = 1.266$, $p > 0.05$, partial $\eta^2 = 0.018$]. Post Hoc analysis using Tukey's multiple comparisons showed that there were significant differences ($p < 0.05$) across all three age groups. As there was no significant interaction between age and stimuli, no further analysis was carried out. It can be summarized that there was a significant effect of age ($p < 0.05$) for both vowels and consonants and the three age groups were significantly different from each other for the two types of stimuli.

Considering that the sample sizes across age groups were unequal, the data was also tested using non parametric tests. As in parametric tests, the results of Kruskal Wallis H test revealed significant effect of age on scores of Articulation Correction Test for both vowels ($\chi^2(2) = 35.319$, $p < 0.01$) and consonants ($\chi^2(2) = 52.210$, $p < 0.01$). Pairwise comparisons using Mann-Whitney U test showed a significant difference ($p < 0.05$) across the three age groups for both vowels and consonants.

4. Effect of Age and Stimuli on the Error Patterns in the Articulation Correction Test

Analyses of the error responses in the Articulation Correction Test were carried out to understand the nature of articulatory errors. The Articulation Correction Test required the participants to correctly produce the stimulus item whenever the presented stimuli were judged as incorrect. The responses were analyzed for correct production of the target vowels and consonants. A score of 1 and 0 was given for every correct and incorrect production respectively. For example, when the word /pensIl/ was presented as /kensIl/ (target stimulus involves substitution of /k/ for /p/), the child was expected to judge the stimulus as incorrect and then correctly produce the target word. In response, if the child said /pensIl/, a score of 1 was given as the target consonant /p/ was produced correctly. If the child did not produce the target consonant /p/, then a score of 0 was given. The responses of individual participants in each age group were analysed and total scores for vowels and consonants were derived separately. The maximum possible score for individual participant was 33 for vowel as well as consonant stimuli. The mean, standard deviation and median of the scores of correct production of target vowels and consonants in the Articulation Correction Test, in the three age groups are given in Table 22.

Table 22

Mean, Standard Deviation (SD) and Median of the Scores obtained by Participants for Correct Production of Target Vowels and Consonants in the Articulation Correction Test

Age Group (in years)	N	Vowels			Consonants		
		Mean	SD	Median	Mean	SD	Median
>3;6 - ≤4;0	24	23.41	4.96	24.50	21.95	3.47	22.00
>4;0 - ≤4;6	60	25.96	3.75	26.00	26.08	3.63	26.00
>4;6 - ≤5;0	60	28.53	2.97	29.00	28.75	3.13	29.00

Note: Maximum score = 33

The mean scores increased as the age increased for both vowels and consonants. Shapiro-Wilk's test of normality revealed that the data was distributed non-normally ($p < 0.05$) in the >4;6 - ≤5;0 years age group, and hence, non-parametric tests were used. Kruskal Wallis H test was used to analyze the effect of age on the scores of correct production of target vowels and consonants. The results revealed significant effect of age on the scores of both vowels [$\chi^2(2) = 26.189$, $p < 0.01$] and consonants [$\chi^2(2) = 43.642$, $p < 0.01$]. Pairwise comparisons using Mann-Whitney U test showed that there were significant differences ($p < 0.05$) across the three age groups for both vowels and consonants.

Wilcoxon Signed Rank test was used to compare between the scores of vowels and consonants within each age group. The results did not show significant difference ($p > 0.05$) between the scores of vowels and consonants in any of the three age groups ($|Z| = 1.821$, 0.340 and 0.587 for >3;6 - ≤4;0 years, >4;0 - ≤4;6 years and >4;6 - ≤5;0

years respectively). Figure 10 depicts the scores obtained (in percentage) by the three groups of participants with respect to correct production of target vowels and consonants in the Articulation Correction Test. Although there were no statistically significant differences in the scores between vowels and consonants in any of the age groups, it may be observed that higher scores were obtained for vowels than consonants in the age group of >3;6 - ≤4;0 years. On the other hand, the scores were similar for both vowels and consonants in the age group of >4;0 - ≤4;6 and >4;6 - ≤5;0 years.

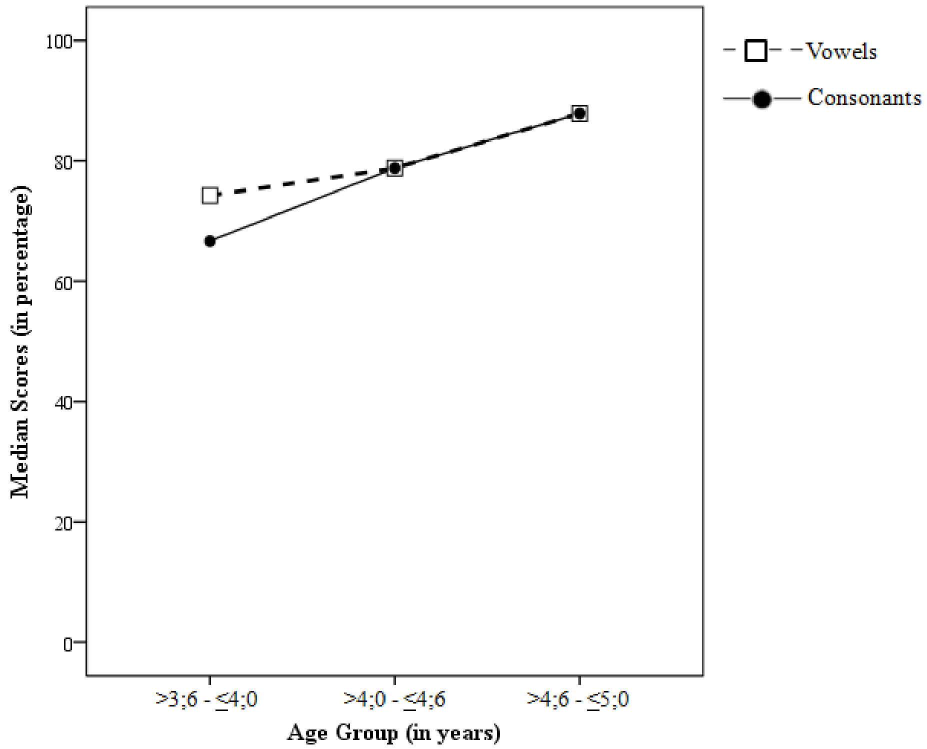


Figure 10. Median Scores (in Percentage) for Correct Production of Target Vowels and Consonants in the Articulation Correction Tests.

To summarize, analyses of the articulation of participants in Articulation Correction Test showed increased scores for correct production of target vowels and consonants with increase in age. Further, although statistically insignificant, scores obtained for correct production of target vowels were higher than that of consonants in the lower age group while no such differences were observed in the higher age groups.

5. Effect of Age and Stimuli on the Scores of Sentence Imitation Test

The Sentence Imitation Test required the participants to listen to a total of 20 audio recorded sentences presented one after another and repeat verbatim. The responses of the participants were recorded and analyzed for total number of words, syllables, word shapes and syllable shapes. The mean, standard deviation and median of the total number of words and syllables, and the number of individual word shapes and syllable shapes produced by participants in each of the age groups are presented in Table 23 and 24. The mean scores of the total number of words and the total number of syllables produced by the participants increased with increase in age. Among the word shapes, mean scores for bisyllables were similar across age groups, whereas the mean scores increased with increase in age for other word shapes. Among the syllable shapes, mean scores were found to be similar across age groups for VC (Vowel-Consonant) and V (Vowel) while the mean scores increased with increase in age for CV (Consonant-Vowel) and CVC (Consonant-Vowel-Consonant).

Table 23

Mean, Standard Deviation (SD) and Median of the Scores for Various Word Shapes in Participants across Age Groups

Word Shapes (Maximum score)		Age Group (in years)			
		>3;0 - ≤3;6	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
Bisyllables (30)	Mean	35.16	35.56	35.05	35.16
	SD	5.87	4.85	4.15	3.86
	Median	35.00	36.00	36.00	35.00
Trisyllables (33)	Mean	20.65	23.86	27.01	27.35
	SD	5.56	5.62	4.56	5.28
	Median	21.00	23.50	27.00	27.00
Four syllables (18)	Mean	13.60	14.60	16.43	16.98
	SD	3.64	3.02	3.41	2.48
	Median	13.50	15.50	16.50	17.00
Five syllables (5)	Mean	2.06	3.30	3.28	3.53
	SD	1.36	1.75	1.79	1.72
	Median	2.00	3.00	3.00	3.00
Six syllables (2)	Mean	0.83	0.90	0.93	1.16
	SD	0.88	0.75	0.84	0.80
	Median	1.00	1.00	1.00	1.00
Seven Syllables (1)	Mean	0.13	0.33	0.33	0.51
	SD	0.38	0.50	0.47	0.53
	Median	0.00	0.00	0.00	0.50
Total (89)	Mean	72.95	78.73	83.25	84.96
	SD	10.94	8.08	5.16	4.16
	Median	73.50	80.00	84.00	86.00

Table 24

Mean, Standard Deviation (SD) and Median of the Scores for Various Syllable Shapes in Participants across Age Groups

Syllable Shapes (Maximum score)		Age Group (in years)			
		>3;0 - ≤3;6	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
VC (10)	Mean	7.10	6.90	6.78	7.03
	SD	1.61	1.33	1.57	1.31
	Median	7.00	7.00	7.00	7.00
CV (218)	Mean	152.28	170.53	186.21	192.18
	SD	26.90	24.73	18.15	17.37
	Median	154.00	171.50	187.50	195.00
V (7)	Mean	10.18	10.76	10.78	10.86
	SD	1.89	2.09	1.93	1.34
	Median	10.00	10.50	11.00	11.00
CVC (40)	Mean	32.81	36.50	37.36	38.31
	SD	6.08	4.65	3.78	2.60
	Median	33.00	37.00	38.00	38.00
Total (275)	Mean	203.45	225.53	241.80	249.13
	SD	33.30	28.13	19.82	17.42
	Median	207.50	229.00	243.00	252.50

Note: VC= Vowel-Consonant; CV = Consonant -Vowel; V = Vowel; CVC = Consonant-Vowel-Consonant

Shapiro-Wilk's test of normality revealed that the data was distributed non-normally ($p < 0.05$) for few of the word shapes and syllable shapes in all the age groups. Hence, non-parametric measures were used to analyze the total number of words and syllables, and the individual word and syllable shapes produced by the participants. Kruskal Wallis H test was administered to study the effect of age on the target scores. In instances where a significant difference was obtained, pairwise comparisons were carried out using Mann-Whitney U test. The results are presented separately for word shapes and syllable shapes.

A. Word Shapes

Kruskal Wallis H test revealed significant effect of age on the total scores for word shapes [$\chi^2(3) = 57.602$, $p < 0.01$]. The effect of age was also found to be significant on the scores for trisyllables [$\chi^2(3) = 48.222$, $p < 0.01$], four syllables [$\chi^2(3) = 38.296$, $p < 0.01$], five syllables [$\chi^2(3) = 26.254$, $p < 0.01$] and seven syllables [$\chi^2(3) = 19.744$ $p < 0.01$] but not for bisyllables [$\chi^2(3) = 0.584$, $p > 0.05$] and six syllables [$\chi^2(3) = 7.668$, $p > 0.05$].

Pairwise comparisons using Mann-Whitney U test showed that the scores obtained by participants in the age group of >3;0 - ≤3;6 years were significantly different ($p < 0.05$) from that of >4;0 - ≤4;6 and >4;6 - ≤5;0 years for all word shapes. Similarly, participants aged >3;0 - ≤3;6 years were significantly different in their use of all word shapes compared to participants in the age range of >3;6 - ≤4;0 years, except four syllables. On the other hand, participants in the age range of >3;6 - ≤4;0 years differed significantly from those in >4;0 - ≤4;6 years and >4;6 - ≤5;0 years in terms of the total score for word shapes, trisyllables and four syllables but there was no significant difference for five and seven syllables. Furthermore, there was no significant difference ($p > 0.05$) between participants in the age group of >4;0 - ≤4;6 and >4;6 - ≤5;0 years for any of the word shapes except for the total score obtained for word shapes ($p < 0.05$). The results of pairwise comparisons using Mann-Whitney U test for word shapes are presented in Table 25.

Results of Kruskal Wallis H test done to analyze the effect of age on the combined scores for polysyllables in general (total scores of four, five, six and seven syllables) revealed significant age effect [$\chi^2(3) = 55.583$, $p < 0.01$]. Pairwise comparisons using

Mann-Whitney U test revealed significant differences in the use of polysyllables across all age groups ($p < 0.05$), except between >4;0 - ≤4;6 and >4;6 - ≤5;0 years.

Table 25

Results of Pairwise Comparisons using Mann-Whitney U Test for Word Shapes

Pairs of Age Group (in years)		|Z|				
		Word Shapes				
		Total	Tri-syllables	Four Syllables	Five Syllables	Seven Syllables
>3;0 - ≤3;6	>3;6 - ≤4;0	2.981**	2.815**	1.831	3.958**	2.598**
>3;0 - ≤3;6	>4;0 - ≤4;6	5.519**	5.843**	4.095**	3.820**	2.754**
>3;0 - ≤3;6	>4;6 - ≤5;0	6.552**	5.738**	5.398**	4.643**	4.437**
>3;6 - ≤4;0	>4;0 - ≤4;6	3.095**	3.199**	2.825**	0.147	0.129
>3;6 - ≤4;0	>4;6 - ≤5;0	4.427**	3.297**	4.282**	0.485	1.990
>4;0 - ≤4;6	>4;6 - ≤5;0	1.978*	0.323	1.014	0.658	1.900

*Note: * - $p < 0.05$, ** - $p < 0.01$*

B. Syllable Shapes

Kruskal Wallis H test revealed a significant effect of age on the total scores obtained for syllable shapes [$\chi^2(3) = 73.187$, $p < 0.01$]. Verification of individual syllable shapes revealed significant effect of age on the scores of consonant vowel (CV) [$\chi^2(3) = 76.731$, $p < 0.01$] and consonant vowel consonant (CVC) [$\chi^2(3) = 33.078$, $p < 0.01$] but not vowel consonant (VC) [$\chi^2(3) = 1.985$, $p > 0.05$] and vowel (V) [$\chi^2(3) = 5.059$, $p > 0.05$].

Pairwise comparisons using Mann-Whitney U test revealed that the scores of >3;0 - ≤3;6 years age group were significantly different ($p < 0.05$) from all other age groups for syllable shapes CV and CVC and also the total scores for syllable shapes. There were significant differences between the scores of >3;6 - ≤4;0 years and >4;0 - ≤4;6 years age groups for CV and the total scores but not for CVC. However, scores of participants in the age group of >3;6 - ≤4;0 years were significantly different from that of >4;6 - ≤5;0 years for all syllable shapes. Similarly, significant differences ($p < 0.05$) were observed between >4;0 - ≤4;6 and >4;6 - ≤5;0 years age groups for the total scores on syllable shapes but not for CV and CVC ($p > 0.05$). The results of pairwise comparisons using Mann-Whitney U test for syllable shapes are given in Table 26.

Table 26

Results of Pairwise Comparisons using Mann-Whitney U Test for Syllable Shapes

Pairs of Age Group (in years)		|Z|		
		Syllable Shapes		
		Total	CV	CVC
>3;0 - ≤3;6	>3;6 - ≤4;0	3.528**	3.543**	3.374**
>3;0 - ≤3;6	>4;0 - ≤4;6	6.436**	6.727**	4.292**
>3;0 - ≤3;6	>4;6 - ≤5;0	7.462**	7.517**	5.338**
>3;6 - ≤4;0	>4;0 - ≤4;6	3.192**	3.525**	0.921
>3;6 - ≤4;0	>4;6 - ≤5;0	4.746**	4.825**	2.283*
>4;0 - ≤4;6	>4;6 - ≤5;0	2.000*	1.838	1.256

*Note: * - $p < 0.05$, ** - $p < 0.01$*

The percentage of each type of word shape and syllable shape present in the imitated utterances of participants in all age groups were computed. These were compared with the corresponding values for each type of word and syllable shapes calculated from the target sentence stimuli (Table 7). The percentage of each type of word shape was calculated for each participant using the formula

$$\frac{\text{Number of word shape produced}}{\text{Total number of words produced}} * 100$$

Similarly, the percentage of each type of syllable shape was calculated for each participant using the formula

$$\frac{\text{Number of syllable shape produced}}{\text{Total number of syllables produced}} * 100$$

Table 27 and 28 shows the mean, standard deviation and median of the percentage of various word shapes and syllable shapes produced by participants in each age group. Shapiro-Wilk's test of normality revealed that the data was distributed non-normally ($p < 0.05$). The standard deviation was also found to be high for few variables. Hence, non-parametric test was applied to compare the percentage of various word shapes and syllable shapes produced in each age group with that of the target values calculated from the sentence stimuli.

Table 27

Mean, Median and Standard Deviation (SD) of Percentages of Various Word Shapes in Participants across Age Groups

Word Shapes (Target %)		Age Group (in years)			
		>3;0 - ≤3;6	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
Bisyllables (33.71)	Mean	48.45	45.44	42.25	41.50
	SD	6.32	6.40	5.72	5.47
	Median	47.53	45.52	41.76	40.70
Trisyllables (37.08)	Mean	28.10	30.14	32.36	32.00
	SD	5.49	5.47	4.61	5.11
	Median	27.54	31.29	32.27	31.81
Four syllables (20.22)	Mean	18.64	18.50	19.67	20.01
	SD	4.42	3.26	3.70	2.91
	Median	18.06	19.23	19.76	20.12
Five syllables (5.62)	Mean	2.83	4.13	3.95	4.14
	SD	1.86	2.13	2.24	2.00
	Median	2.61	4.47	3.87	3.90
Six syllables (2.25)	Mean	1.10	1.13	1.10	1.37
	SD	1.15	0.94	0.97	0.95
	Median	1.25	1.20	1.17	1.22
Seven Syllables (1.12)	Mean	0.16	0.41	0.3	0.59
	SD	0.47	0.64	0.55	0.62
	Median	0.00	0.00	0.00	0.54

Table 28

Mean, Median and Standard Deviation (SD) of Percentages of Various Syllable Shapes in Participants across Age Groups

Syllable Shapes (Target %)		Age Group (in years)			
		>3;0 - ≤3;6	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
VC (2.55)	Mean	3.52	3.09	2.80	2.82
	SD	0.80	0.67	0.63	0.52
	Median	3.35	3.05	2.71	2.88
CV (79.27)	Mean	74.70	75.43	76.92	77.03
	SD	2.28	2.20	1.91	2.01
	Median	75.15	75.52	76.94	77.37
V (3.64)	Mean	5.06	4.85	4.48	4.38
	SD	0.87	1.20	0.86	0.63
	Median	4.96	4.66	4.37	4.35
CVC (14.55)	Mean	16.15	16.23	15.50	15.44
	SD	1.93	1.46	1.62	1.37
	Median	16.14	15.99	15.38	15.12

Note: VC= Vowel-Consonant; CV = Consonant -Vowel; V = Vowel; CVC = Consonant-Vowel-Consonant

One-Sample Wilcoxon Signed Rank Test was used and the results revealed significant differences ($p < 0.05$) for all word shapes in the four age groups except for four syllables (in >4;0 - ≤4;6 years and >4;6 - ≤5;0 years) where the percentages did not vary significantly from the target ($p > 0.05$). Comparison of the percentage of polysyllables (combined scores of four, five, six and seven syllables) showed significant differences ($p < 0.01$) in each of the age groups i.e. the percentage of polysyllables was lower than the target value in all the age groups. On the other hand, significant differences ($p < 0.05$) were obtained for all the syllable shapes in each of the four age groups.

The percentages of word shapes and syllable shapes produced by participants across age groups are depicted in Figures 11 and 12 respectively. It is observed that the percentage of bisyllables produced is considerably higher than the target in all the age groups. The increase in percentage of bisyllables was more pronounced in the younger age groups compared to the higher age groups.

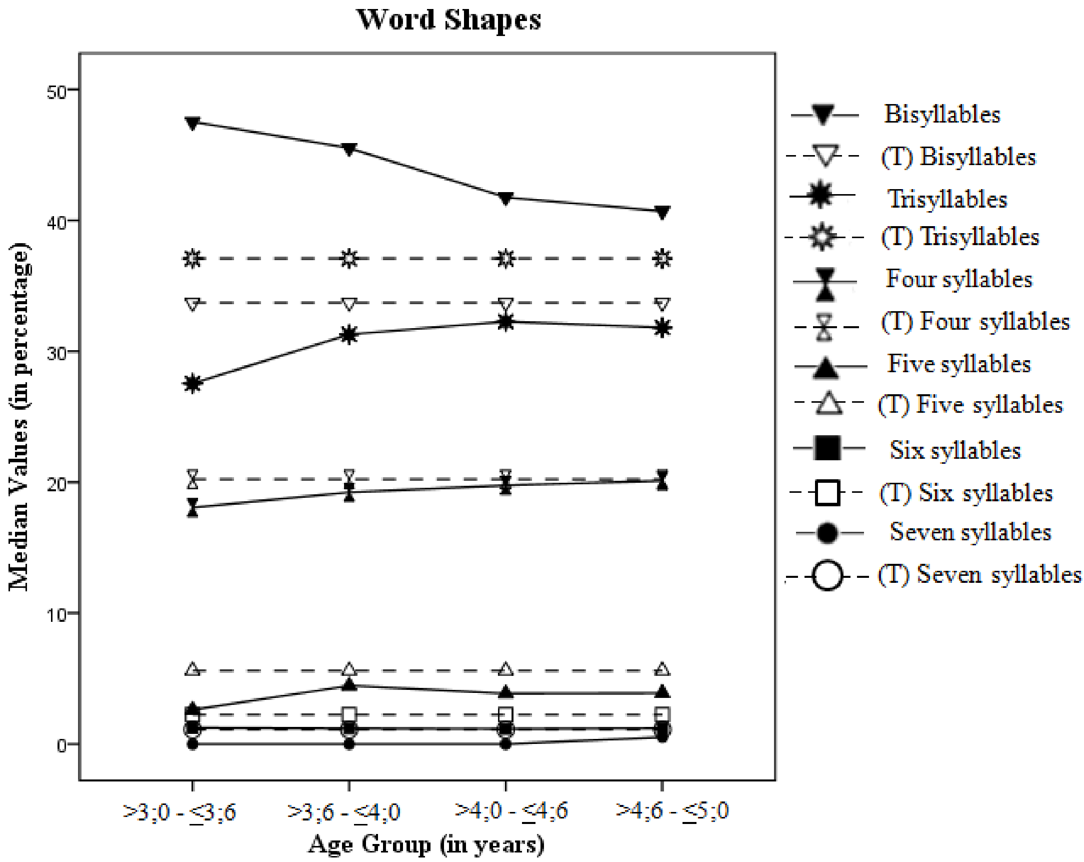


Figure 11. Percentages of Various Word Shapes Produced by Participants with Respect to their Corresponding Target Values.

Note: T = Target

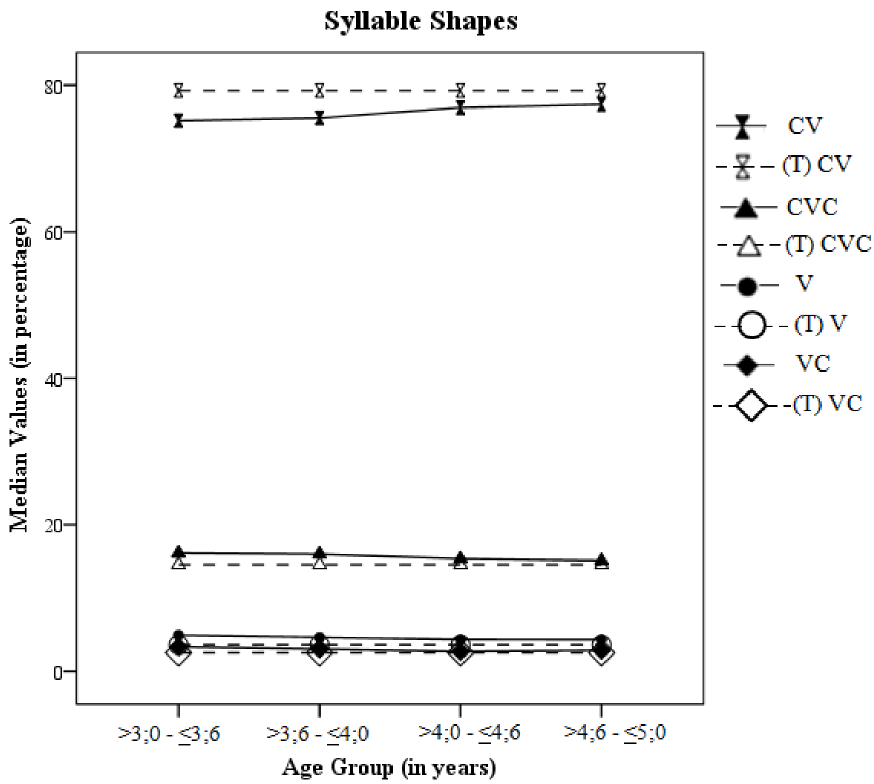


Figure 12. Percentages of Various Syllable Shapes Produced by Participants with Respect to their Corresponding Target Values.

Note: T = Target

To summarize, there was a significant effect of age on the total number of words and syllables produced by participants in the typically developing group. The total number of words and the number of various word shapes produced by participants increased with increase in age except for bisyllables. Similarly, the total number of syllables and the number of various syllable shapes produced increased with increase in age except for V and VC. Comparison of the percentage of each type of word and syllable shape in the imitated utterances with the corresponding target values revealed significant differences for all word shapes and syllable shapes. In particular, the percentage of bisyllables produced by the participants was greater than the target values and the difference was more distinct in the younger age groups.

6. Effect of Age and Stimuli on the Time Taken in Rapid Automatized Naming (RAN) Tests

The time taken (in seconds) by individual participants in each of the three trials of the RAN Nouns, RAN Verbs and RAN Size tests were measured. Cronbach's Alpha Test was used to check reliability across the three trials of each of the RAN tests and the results are presented in Table 29. A good reliability was observed for all the three RAN tests in each of the four age groups. Therefore, the time taken in the three trials of each of the RAN tests was averaged and the averaged scores were subjected to further analyses.

Table 29

Results of Cronbach's Alpha Test for the Reliability across Three Trials of each of the RAN Tests in the Four Age Groups

Subsection	Age Group (in years)			
	>3;0 - ≤3;6	>3;6 - ≤4;0	>4;0 - ≤4;6	>4;6 - ≤5;0
RAN Nouns	0.932	0.929	0.950	0.954
RAN Verbs	0.772	0.944	0.962	0.917
RAN Size	0.939	0.948	0.924	0.956

The mean, median and standard deviation of the average time taken for each of the three RAN tests, namely RAN Nouns, RAN Verbs and RAN Size in the four age groups are presented in Table 30. The mean time taken to complete the test was highest in the youngest age group and it decreased as the age range increased in each of the RAN tests. Among the three RAN tests, the mean time taken was least for RAN Size followed by RAN Nouns and RAN Verbs.

Table 30

Mean, Standard Deviation (SD) and Median of the Average Time Taken (in seconds) by the Participants in the Three RAN tests

Subsection		Age Group (in years)			
		>3;0 - ≤3;6 (N=60)	>3;6 - ≤4;0 (N=60)	>4;0 - ≤4;6 (N=60)	>4;6 - ≤5;0 (N=60)
RAN Nouns	Mean	110.30	104.65	92.29	92.70
	SD	14.75	14.29	16.48	10.63
	Median	107.50	106.16	94.50	93. 33
RAN Verbs	Mean	119.70	123.05	115.90	110.12
	SD	10.11	16.00	17.94	10.21
	Median	119. 00	124.16	114.83	109.83
RAN Size	Mean	78.72	76.47	65.21	62.01
	SD	13.83	13.47	12.08	8.49
	Median	77.50	77.50	64.66	62.33

Shapiro-Wilk's test of normality revealed normal distribution of the data for all three RAN tests in each age group and hence, parametric tests were applied. Sphericity was assumed ($p > 0.05$) based on the results of Mauchly's test of Sphericity.

Repeated measures ANOVA with age as between-subject factor (Mixed ANOVA) was used to test the effect of stimuli on the time taken in RAN tests. The results revealed a significant main effect of both age [$F(3, 236) = 24.464$, $p < 0.01$, partial $\eta^2 = 0.237$] and stimuli [$F(2, 472) = 1736.73$, $p < 0.01$, partial $\eta^2 = 0.880$]. There was a significant interaction between age and stimuli [$F(6, 472) = 7.258$, $p < 0.01$, partial $\eta^2 = 0.084$]. Pairwise comparisons using Bonferroni's test adjusted for multiple comparisons revealed significant differences across all age groups ($p < 0.05$). Post hoc analysis using Tukey's multiple comparisons revealed significant difference ($p < 0.05$) across all age groups except between >3;0 - ≤3;6 years and >3;6 - ≤4;0 years and between >4;0 - ≤4;6 and >4;6 - ≤5;0 years.

As there was significant interaction between age and stimuli, the independent effects of each of these were verified. One-way MANOVA was used to compare the time taken by participants across age groups in the three RAN tests. The results revealed a significant effect of age [$F(9, 569) = 12.22$, $p < 0.01$, Wilk's $\Lambda = 0.651$, partial $\eta^2 = 0.133$]. Subsequent analyses using Univariate ANOVAs revealed a significant effect of age on the time taken for RAN Nouns [$F(3, 236) = 23.811$, $p < 0.01$, partial $\eta^2 = 0.232$], RAN Verbs [F(3, 236 = 9.406, $p < 0.01$), partial $\eta^2 = 0.107$] and RAN Size [$F(3, 236) = 27.487$, $p < 0.01$, partial $\eta^2 = 0.259$] tests. Post Hoc analysis using Tukey's multiple comparisons showed significant differences ($p < 0.05$) across all age groups except between >3;0 - ≤3;6 years and >3;6 - ≤4;0 years, and between >4;0 - ≤4;6 years and >4;6 - ≤5;0 years on RAN tests for Nouns and Size. On the other hand, no significant differences ($p > 0.05$) were obtained between the age groups >3;0 - ≤3;6 years and >3;6 - ≤4;0 years, >3;0 - ≤3;6 years and >4;0 - ≤4;6 years and >4;0 - ≤4;6 and >4;6 - ≤5;0 years on RAN test for Verbs.

Further, one-way repeated measure ANOVA was used to compare the time taken across the three RAN tests within each age group. Results revealed significant differences across the three RAN tests in each of the four age groups, >3;0 - ≤3;6 years [$F(2, 118) = 294.563$, $p < 0.01$, partial $\eta^2 = 0.833$] , >3;6 - ≤4;0 years [$F(2, 118) = 598.034$, $p < 0.01$, partial $\eta^2 = 0.910$], >4;0 - ≤4;6 years [$F(2, 118) = 297.469$, $p < 0.01$, partial $\eta^2 = 0.834$] and >4;6 - ≤5;0 years [$F(2, 118) = 1273.955$, $p < 0.01$, partial $\eta^2 = 0.956$]. Post Hoc analysis using Bonferroni's test adjusted for multiple comparisons revealed significant differences ($p < 0.05$) across all three RAN tests in each age group.

Therefore, a significant effect of age was observed in the performance of typically developing participants on each of the RAN tests – Nouns, Verbs and Size. The time taken by participants to complete each of the RAN tests decreased with increase in age. However, the difference in time taken was not significant in few of the adjacent age groups, particularly for RAN Verbs. The effect of stimuli was also found to be significant with differences observed across all three RAN tests in each of the age groups. Participants in each age group performed RAN test for Size the fastest, followed by RAN Nouns and RAN Verbs.

III. Comparison of Performance of Participants in the Typically Developing Group and Clinical Group in Various Subsections of the Test Battery

The test battery standardized on typically developing participants was administered on children with developmental disorders (Clinical Group) in order to check for the clinical utility of the test developed. Participants in the Clinical group included children with Speech Sound Disorder (SSD), Specific Language Impairment (SLI), at risk for Dyslexia and Childhood Apraxia of Speech (CAS). This section addresses the fourth objective of the study i.e., to investigate and compare the performance of children with developmental disorders with that of the typically developing children in various subsections of the test battery.

The performance of participants in the clinical group in various subsections of the test battery is presented under the following heads:

1. Comparison between composite scores of clinical group and the typically developing group

2. Comparison of performance of each clinical group with the typically developing group and, across various clinical groups
3. Performance profiles of clinical groups
4. Performance profile of individual participants in the clinical group

1. Comparison between Composite Scores of Clinical Group and the Typically Developing Group

Reliability of performance was tested by comparing scores across the three trials in each of the Articulation Judgment tests and RAN tests. The results of Cronbach's Alpha test, as shown in Table 31, revealed good reliability in both the tests in typically developing group as well as clinical group. Hence, average of the scores of the three trials of RAN tests and Articulation Judgment tests were computed for the two groups of participants and the averaged scores were subjected to further analyses.

Table 31
Results of Cronbach's Alpha Test for the Reliability across Three Trials of Articulation Judgment and RAN Tests in the Typically Developing Group and the Clinical Group

Subsection		Typically Developing Group (N=240)	Clinical Group (N=30)
Articulation Judgment	Vowels	0.903	0.912
	Consonants	0.874	0.939
Rapid Automatized Naming	Nouns	0.952	0.963
	Verbs	0.930	0.974
	Size	0.954	0.970

The mean, standard deviation and median of the scores obtained by participants in the typically developing group and clinical groups (composite scores of children with SSD, children with SLI, children with CAS and children at risk for dyslexia) in various subsections of the test battery are presented in Table 32. The mean scores of the participants in the clinical group were lower than that of the typically developing group on each of the tests.

Table 32

Mean, Standard Deviation (SD) and Median of the Scores Obtained by Participants in the Typically Developing Group and Clinical Group in Various Subsections of the Test Battery

Subsection (Maximum score)		Typically Developing Group (N=240)			Clinical Group (N=30)		
		Mean	SD	Median	Mean	SD	Median
Articulation Judgment	Vowels (66)	58.40	3.21	58.33	48.44	4.53	48.00
	Consonants (66)	59.09	2.81	59.00	49.79	4.26	51.00
Articulation Correction	Vowels (132)	117.33	8.07	119.00	89.28	16.63	93.00
	Consonants (132)	117.78	7.91	119.00	90.50	16.33	88.50
Sentence Imitation	Total words (89)	79.98	8.85	82.00	74.62	15.10	81.00
	Total syllables (275)	229.98	30.82	235.00	203.17	48.60	216.00
Rapid Automatized Naming (RAN)	Nouns	99.99	16.11	101.00	114.84	26.06	110.17
	Verbs	117.20	14.73	117.00	137.89	26.04	128.17
	Size	70.61	14.03	68.50	86.22	22.91	80.00

Note: The RAN values are given as time taken (in seconds)

Shapiro-Wilk's test of normality revealed that the data was distributed non-normally ($p < 0.05$) for some of the subsections. Hence, non-parametric measures were used for analyses. Mann-Whitney U test was used to compare the composite scores obtained by participants in the clinical group with that of the typically developing group in various subsections of the test battery. The results indicated a significant difference ($p < 0.01$) in scores between the typically developing group and the clinical group for all subsections except for total number of words produced in the Sentence Imitation Test. The results of Mann-Whitney U test are presented in Table 33. The median scores obtained by participants in the typically developing group and the clinical group in various subsections of the test battery are depicted in Figure 13.

Table 33

Results of Mann-Whitney U Test Comparing Scores of Participants in the Typically Developing Group and Clinical Group in Various Subsections of the Test Battery

Subsection		|Z|
Articulation Judgment	Vowels	7.102**
	Consonants	7.141**
Articulation Correction	Vowels	6.605**
	Consonants	6.360**
Sentence Imitation	Total words	1.473
	Total syllables	2.895**
Rapid Automatized Naming (RAN)	Nouns	3.232**
	Verbs	4.081**
	Size	3.891**

*Note: ** - $p < 0.01$*

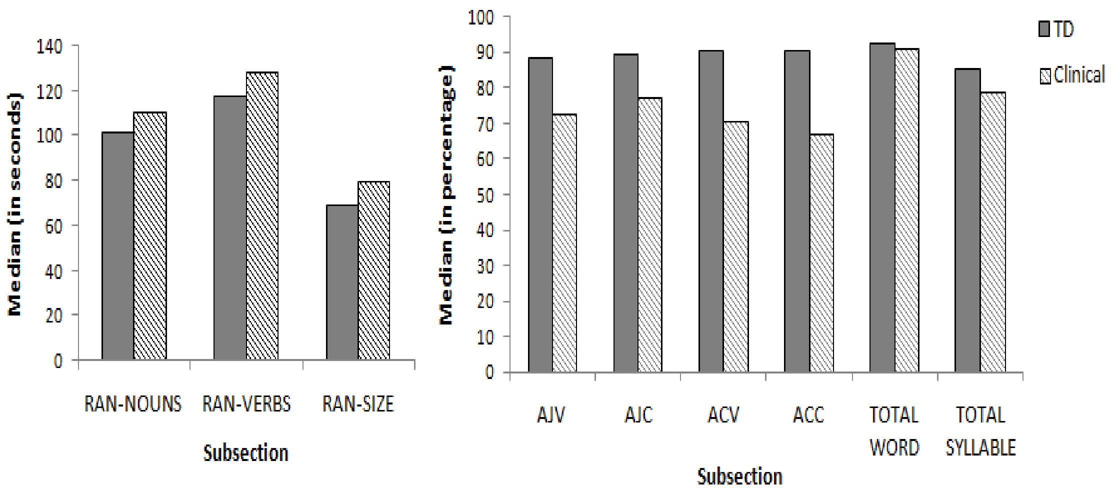


Figure 13. Median Scores in the Typically Developing Group and Clinical Group in Various Subsections of the Test Battery.

2. Comparison of Performance of each Clinical Group with the Typically Developing Group and across various Clinical Groups

The performance of participants in each of the clinical group is compared with that of the typically developing group and also across the various clinical groups. Only one of the three participants in the CAS group could complete the test battery, and hence the data for CAS is not included for group comparisons and is presented separately.

Reliability of performance was tested by comparing scores across the three trials in each of the Articulation Judgment tests and RAN tests. The results, as presented in Table 34, indicated good reliability for each of the tests in the three clinical groups. Hence, average of the scores of the three trials of each Articulation Judgment test and RAN test were computed for each clinical group and the averaged scores were subjected to further analyses.

Table 34

Results of Cronbach's Alpha Test for the Reliability across Three Trials of Articulation Judgment and RAN Tests in the Clinical Groups

Subsection	Group		
	SSD	ARD	SLI
AJ Vowels	0.878	0.969	0.938
AJ Consonants	0.913	0.976	0.913
RAN Nouns	0.932	0.909	0.974
RAN Verbs	0.978	0.739	0.962
RAN Size	0.936	0.826	0.974

Note: AJ =Articulation Judgment; RAN = Rapid Automatized Naming; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment

Non-parametric tests were carried out to compare the performance across groups considering the small and unequal sample sizes within the clinical groups. Kruskal Wallis H test was administered to study the effect of group on the scores obtained in various subsections of the test battery. This was followed by Mann-Whitney U test for pairwise comparisons whenever significant difference was obtained. The results in this section are presented separately for each subsection of the test battery.

A. Articulation Judgment and Articulation Correction Tests for Vowels and Consonants

The mean, standard deviation and median of scores in the Receptive Picture Vocabulary Test for the typically developing group and clinical groups (Children with SSD, children at risk for dyslexia and children with SLI) are presented in Table 35.

Table 35

Mean, Standard Deviation (SD) and Median of the Scores of Typically Developing Group and Clinical Groups in the Receptive Picture Vocabulary Test

Group	N	Mean	SD	Median
Typically Developing	240	32.52	0.73	33
Speech Sound Disorder	11	32.00	1.00	32
At risk for Dyslexia	7	32.57	0.78	33
Specific Language Impairment	9	31.66	1.00	32

Note: Maximum score = 33

The mean, standard deviation and median of the scores obtained by participants in the typically developing group and clinical groups (children with SSD, children at risk for dyslexia and children with SLI) on Articulation Judgment and Articulation Correction Tests are presented in Table 36. It is observed that participants in each clinical group obtained lower mean scores on each of the tests compared to the typically developing group. Among the clinical groups, the group at risk for Dyslexia had higher scores followed by SSD and SLI group in each of the Articulation Judgment and Articulation Correction Tests.

Table 36

Mean, Standard Deviation (SD) and Median of the Scores of Typically Developing Group and Clinical Groups in the Articulation Judgment and Articulation Correction Tests for Vowels and Consonants

Subsection (Maximum score)		Group			
		TD (N=144)	SSD (N=9)	ARD (N=7)	SLI (N=5)
Articulation	Mean	58.39	47.62	50.66	46.40
Judgment –	SD	3.21	3.87	4.55	5.49
Vowels (66)	Median	58.33	47.66	48.00	45.66
Articulation	Mean	59.08	50.00	51.00	47.46
Judgment –	SD	2.81	3.62	4.86	4.87
Consonants (66)	Median	59.00	51.33	47.66	45.66
Articulation	Mean	117.32	86.66	102.42	75.00
Correction –	SD	8.07	16.46	10.98	12.42
Vowels (132)	Median	119.00	87.00	97.00	75.00
Articulation	Mean	117.78	92.55	96.14	79.80
Correction –	SD	7.90	16.48	17.46	13.62
Consonants (132)	Median	119.00	95.00	86.00	75.00

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment

Kruskal Wallis H test revealed significant group effect on scores obtained in the Articulation Judgment Test for vowels [$\chi^2(3) = 48.623$, $p < 0.01$] and consonants [$\chi^2(3) = 49.068$, $p < 0.01$] and also Articulation Correction Test for vowels [$\chi^2(3) = 42.875$, $p < 0.01$] and consonants [$\chi^2(3) = 39.290$, $p < 0.01$]. This was followed by Mann Whitney U test and the results of pairwise comparisons are given in Table 37.

There was a significant difference between typically developing group and each of the clinical groups in both Articulation Judgment and Articulation Correction Tests. However, there was no significant difference among the clinical groups in any of the tests, except for a significant difference between SLI and at risk for dyslexia groups in Articulation Correction of vowels.

Table 37

Results of Pairwise Comparisons Using Mann-Whitney U Test for Articulation Judgment and Articulation Correction Tests for Vowels and Consonants

	|Z|			
	Articulation Judgment		Articulation Correction	
	Vowels	Consonants	Vowels	Consonants
TD – SSD	4.946*	4.947*	4.700*	4.373*
TD - SLI	3.702*	3.755*	3.783*	3.798*
TD - ARD	3.826*	3.844*	3.101*	3.003*
SSD - SLI	0.334	0.601	1.267	1.336
SSD - ARD	1.008	0.371	1.855	0.477
SLI - ARD	1.467	1.546	2.766*	1.548

*Note: * - $p < 0.05$; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; ARD = At Risk for Dyslexia*

The error patterns in the responses of Articulation Judgment Test were analyzed for participants in each of the clinical groups and compared with that of the typically developing group. The error patterns of vowels were analyzed in terms of tongue height and tongue advancement whereas consonants were analyzed for place of articulation, manner of articulation and voicing. Figures 14 to 18 represent the percentage of each error pattern for vowels and consonants in the clinical groups compared to the typically developing group.

From Figures 14 to 18, it is observed that the error percentages for both vowels and consonants were least for participants in the typically developing group. Among the clinical groups, the percentage of errors was highest in children with SLI, followed by children with SSD and least in children at risk for dyslexia. Although the percentage of errors in the clinical groups is greater when compared to the typically developing group, the patterns of errors are more or less similar to that of typically developing group. This is particularly true for errors in vowels whereas certain deviations are present in the error patterns of consonants. With respect to place and manner of articulation, the patterns of errors in children with SLI and children with SSD were different compared to the typically developing group.

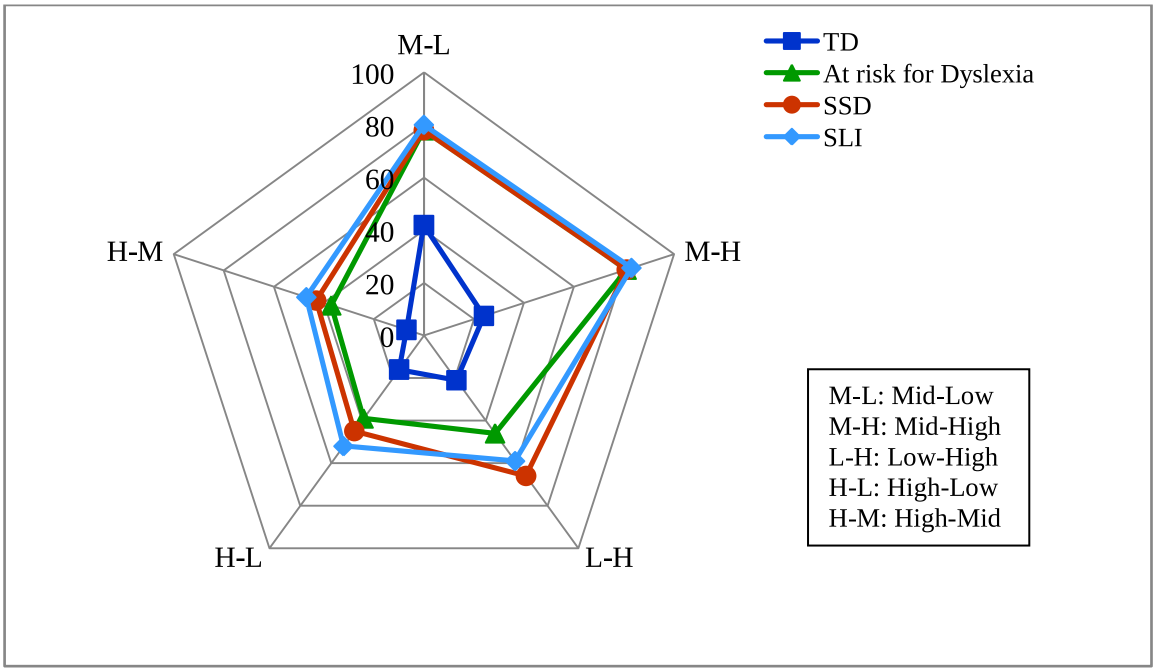


Figure 14. Percentage of Error Patterns in Terms of Tongue Height in the Typically Developing Group and Clinical Groups on Articulation Judgment Test for Vowels.

Note: TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment

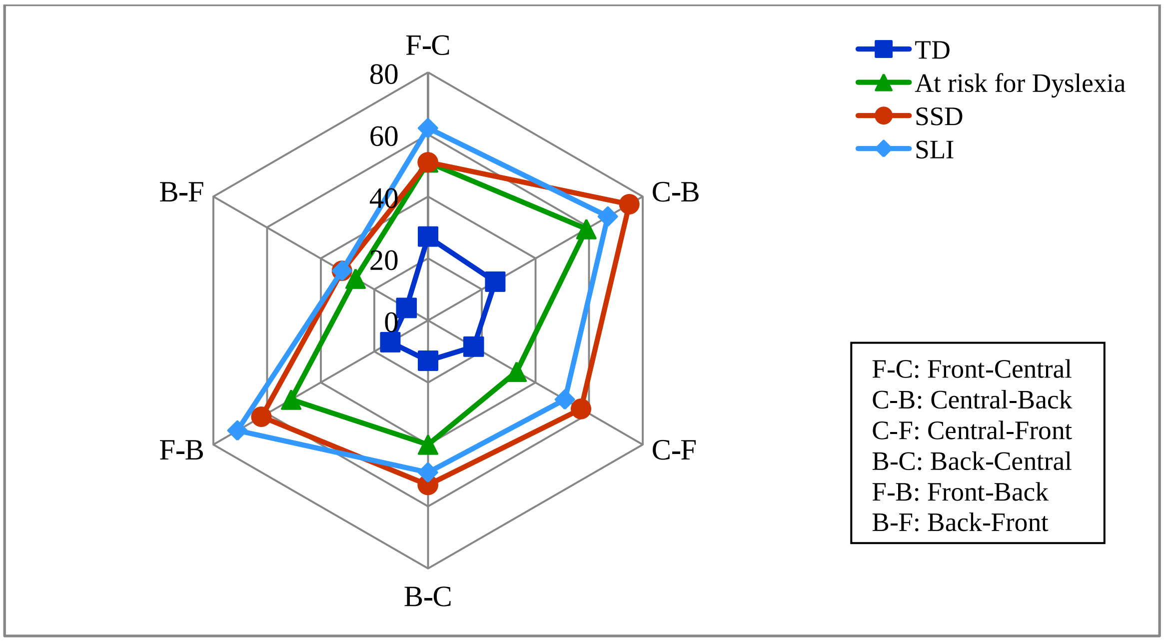


Figure 15. Percentage of Error Patterns in Terms of Tongue Advancement in the Typically Developing Group and Clinical Groups on Articulation Judgment Test for Vowels.

Note: TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment

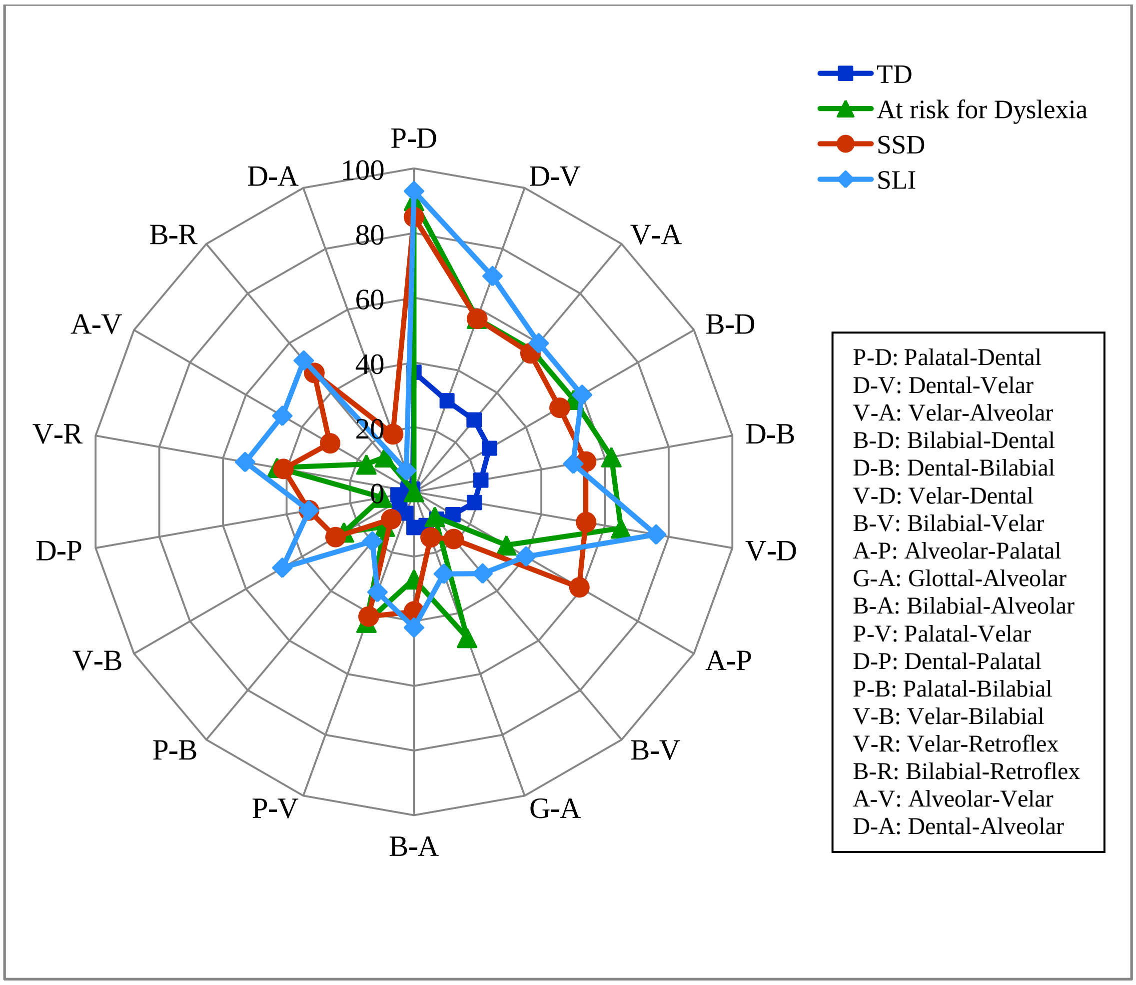


Figure 16. Percentage of Error Patterns in Terms of Place of Articulation in the Typically Developing Group and Clinical Groups on Articulation Judgment Test for Consonants.

Note: TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment

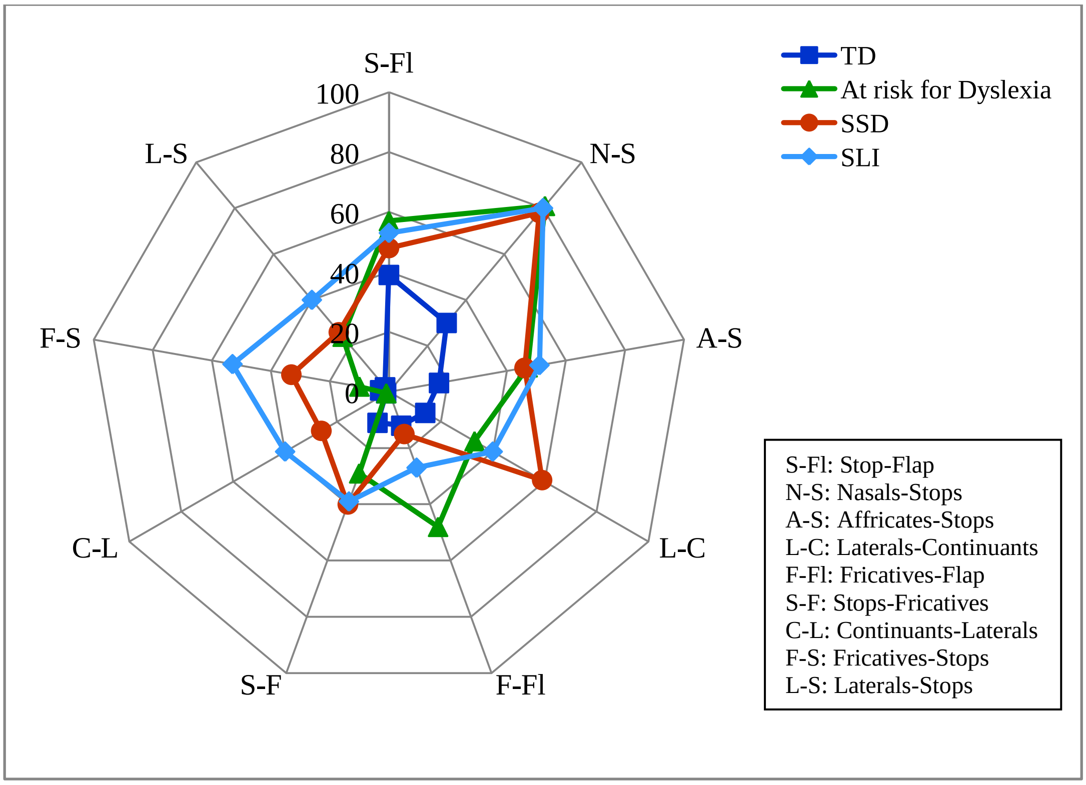


Figure 17. Percentage of Error Patterns in Terms of Manner of Articulation in the Typically Developing Group and Clinical Groups on Articulation Judgment Test for Consonants.

Note: TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment

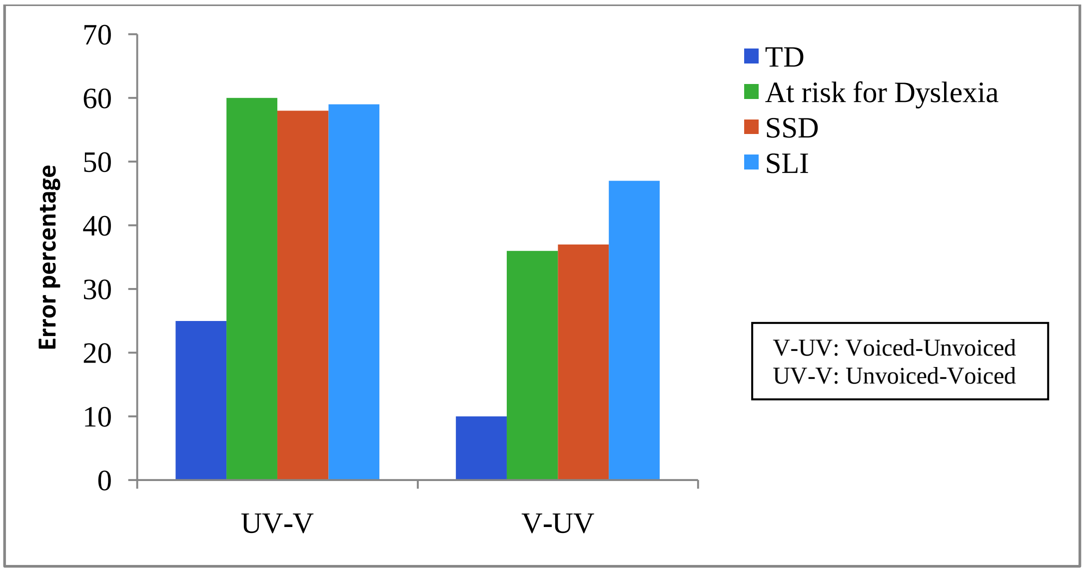


Figure 18. Percentage of Error Patterns in Terms of Voicing in the Typically Developing Group and Clinical Groups on Articulation Judgment Test for Consonants.

Note: TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment

The responses obtained in the Articulation Correction Test were further analysed to check for the correct production of target vowels and consonants in each participant. The mean, standard deviation and median of scores for the correct production of target vowels and consonants in the typically developing group and clinical groups are given in Table 38.

Table 38

Mean, Standard Deviation (SD) and Median of the Scores of Typically Developing Group and Clinical Groups for Correct Production of Target Vowels and Consonants in the Articulation Correction Test

Subsection (Maximum score)		Group			
		TD (N=144)	SSD (N=9)	ARD (N=7)	SLI (N=5)
Articulation Correction – Vowels (33)	Mean	26.61	14.66	22.71	12.00
	SD	4.10	7.59	3.59	4.18
	Median	27.00	15.00	21.00	11.00
Articulation Correction – Consonants (33)	Mean	26.50	15.66	17.42	8.20
	SD	4.13	6.96	8.58	5.49
	Median	27.00	17.00	14.00	5.00

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At risk for Dyslexia; SLI = Specific Language Impairment

Results of Kruskal Wallis H test revealed significant effect of group on the scores obtained for correct production of both target vowels [$\chi^2(2) = 36.762$, $p < 0.01$] and consonants [$\chi^2(2) = 37.541$, $p < 0.01$]. Mann Whitney U test was run subsequently and the results of pairwise comparisons are given in Table 39.

Table 39

Results of Pairwise Comparisons Using Mann-Whitney U Test Comparing Scores of Correct Production of Target Vowels and Consonants in the Articulation Correction Test

	|Z|	
	Vowels	Consonants
TD - SSD	4.399**	4.397**
TD - SLI	3.713**	3.795**
TD – ARD	2.478*	2.636**
SSD - SLI	0.669	1.737
SSD - ARD	1.911	0.106
SLI - ARD	2.770**	1.711

*Note: * - p < 0.05, ** - p < 0.01; TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment*

A significant difference was seen between the scores obtained by the typically developing group and each of the clinical groups for correct production of both target vowels and consonants in the Articulation Correction Test. However, no significant differences were seen among the clinical groups except between children with SLI and children at risk for dyslexia for correct production of target vowels.

B. Sentence Imitation Test

The results of the Sentence Imitation test are presented separately for word shapes and syllable shapes.

i. Word Shapes

The mean, standard deviation and median of the total scores obtained by participants in the typically developing group and clinical groups (children with SSD, children at risk for dyslexia and children with SLI) for various word shapes are presented in Table 40.

Table 40

Mean, Standard Deviation (SD) and Median of the Scores Obtained by Participants in the Typically Developing Group and Clinical Groups on Various Word Shapes

Word Shapes (Maximum score)		Group			
		TD (N=240)	SSD (N=11)	ARD (N=7)	SLI (N=9)
Bisyllables (30)	Mean	35.23	39.54	38.42	33.11
	SD	4.72	7.31	4.64	8.75
	Median	35.00	41.00	37.00	31.00
Trisyllables (33)	Mean	24.72	22.18	24.00	19.55
	SD	5.90	6.36	5.65	9.74
	Median	25.00	22.00	25.00	15.00
Four syllables (18)	Mean	15.40	13.81	15.57	9.44
	SD	3.43	5.09	1.90	4.82
	Median	16.00	13.00	16.00	8.00
Five syllables (5)	Mean	3.04	2.36	4.28	2.33
	SD	1.75	1.62	1.97	3.80
	Median	3.00	2.00	4.00	0.00
Six syllables (2)	Mean	0.95	0.09	0.71	0.33
	SD	0.82	0.30	1.11	0.70
	Median	1.00	0.00	0.00	0.00
Seven syllables (1)	Mean	0.32	0.09	0.28	0.11
	SD	0.49	0.30	0.48	0.33
	Median	0.00	0.00	0.00	0.00
Total words (89)	Mean	79.97	78.36	83.57	65.44
	SD	8.84	11.18	4.61	18.68
	Median	82.00	81.00	84.00	71.00

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment

The mean scores of the total number of words produced by the participants in the SLI group was lower than that of the typically developing group, at risk for dyslexia group and SSD group where the mean scores were similar. A similar trend was observed for each of the word shapes. Further, the mean scores for bisyllables were higher than the maximum scores in each of the groups, whereas the mean scores for other word shapes were lower than the maximum scores.

Results of Kruskal Wallis H test revealed significant effect of group on total number of words produced [$\chi^2(3) = 8.136$, $p < 0.05$]. Significant effect of group was also observed for four syllables [$\chi^2(3) = 13.054$, $p < 0.05$], five syllables [$\chi^2(3) = 8.697$, $p < 0.05$] and six syllables [$\chi^2(3) = 19.468$, $p < 0.05$] but not for bisyllables [$\chi^2(3) = 7.542$, $p > 0.05$], trisyllables [$\chi^2(3) = 5.311$, $p > 0.05$] and seven syllables [$\chi^2(3) = 4.165$, $p > 0.05$]. Results of Kruskal Wallis H test done to analyze the effect of group on the combined scores for polysyllables (total scores of four, five, six and seven syllables) revealed significant group effect [$\chi^2(3) = 11.641$, $p < 0.05$]. The results of pairwise comparisons using Mann-Whitney U test for word shapes are given in Table 41.

Table 41

Results of Pairwise Comparisons using Mann-Whitney U Test for Word Shapes

	|Z|			
	Word Shapes			
	Total	Four Syllables	Five Syllables	Six Syllables
TD - SSD	0.206	1.277	1.325	3.685*
TD - SLI	2.674*	3.405*	2.033*	2.406*
TD - ARD	0.943	0.011	1.706	1.110
SSD - SLI	1.712	1.942	1.201	0.856
SSD - ARD	0.681	1.000	1.901	1.685
SLI - ARD	2.332*	2.339*	1.831	0.840

*Note: * - p < 0.05; TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment*

Typically developing group was found to be significantly different from the SLI group but not from the SSD and at risk for dyslexia groups (except for six syllables between typically developing group and SSD group). There was no significant difference between children with SSD and SLI and between children with SSD and at risk for dyslexia for any of the word shapes. Similarly, children with SLI were found to be different from children at risk for dyslexia in terms of total words and four syllables but not for five and six syllables. Pairwise comparisons for polysyllables revealed significant differences ($p < 0.05$) between children with SLI when compared to both typically developing group and children at risk for Dyslexia but not across any other groups.

ii. Syllable Shapes

The mean, standard deviation and median of the total scores obtained by participants in the typically developing group and clinical groups (children with SSD, children at risk for dyslexia and children with SLI) for various syllable shapes are presented in Table 42.

Table 42

Mean, Standard Deviation (SD) and Median of the Scores Obtained by Participants in the Typically Developing Group and Clinical Groups on Various Syllable Shapes

Syllable Shapes (Maximum score)		Group			
		TD (N=240)	SSD (N=11)	ARD (N=7)	SLI (N=9)
VC (10)	Mean	6.95	7.63	6.71	6.88
	SD	1.46	1.28	1.25	1.76
	Median	7.00	7.00	7.00	7.00
CV (218)	Mean	175.30	162.09	181.71	129.55
	SD	26.94	30.98	17.01	40.26
	Median	177.50	167.00	7.00	125.00
V (7)	Mean	10.65	11.36	11.71	10.22
	SD	1.84	3.41	1.49	5.58
	Median	11.00	11.00	12.00	12.00
CVC (40)	Mean	36.25	32.45	38.42	30.33
	SD	4.90	6.03	2.82	11.03
	Median	37.00	32.00	38.00	36.00
Total syllables (275)	Mean	229.97	210.45	239.14	177.66
	SD	30.82	36.51	18.22	56.61
	Median	235.00	201.00	233. 00	181.00

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; VC= Vowel Consonant; CV = Consonant Vowel; V = Vowel; CVC = Consonant Vowel Consonant

The mean scores of the total number of syllables produced by the participants in the typically developing group, at risk for dyslexia group and SSD group were similar whereas the mean scores were lower in the SLI group. Among the syllable shapes, a similar trend was observed for CV and CVC. However, the mean scores were similar across all groups for the syllable shapes VC and V.

Results of Kruskal Wallis H test showed a significant effect of group on the total number of syllables produced [$\chi^2(3) = 12.354$, $p < 0.05$]. Verification of individual syllable shapes revealed significant effect of group for CV [$\chi^2(3) = 13.159$, $p < 0.05$] and CVC [$\chi^2(3) = 8.333$, $p < 0.05$] but not for VC [$\chi^2(3) = 2.602$, $p > 0.05$] and V [$\chi^2(3) = 3.763$, $p > 0.05$. The results of pairwise comparisons using Mann-Whitney U test for syllable shapes are given in Table 43.

Table 43

Results of Pairwise Comparisons using Mann-Whitney U Test for Syllable Shapes

	|Z|		
	Syllable Shapes		
	Total	CV	CVC
TD - SSD	1.835	1.419	2.334*
TD - SLI	2.956*	3.310*	1.364
TD - ARD	0.633	0.507	1.025
SSD - SLI	1.254	1.786	0.038
SSD - ARD	1.496	1.224	2.410*
SLI - ARD	2.489*	2.707*	1.379

*Note: * - p < 0.05; TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; CV = Consonant-Vowel; CVC = Consonant-Vowel-Consonant*

Children with SLI were found to be significantly different from both typically developing group and children at risk for Dyslexia with respect to the total number of syllables produced and the syllable shape CV. On the other hand, children with SSD differed significantly from the typically developing group and children at risk for Dyslexia with respect to the syllable shape CVC. There was no significant difference across other groups for any of the syllable shapes.

Table 44 and 45 shows the mean, standard deviation and median values of the percentage of various word shapes and syllable shapes produced by participants in the typically developing group and clinical groups (children with SSD, children at risk for dyslexia and children with SLI).

Table 44

Mean, Standard Deviation (SD) and Median of the Percentages of Various Word Shapes in Typically Developing Group and Clinical Groups

Word Shapes (Target %)		Group			
		TD (N=240)	SSD (N=11)	ARD (N=7)	SLI (N=9)
Bisyllables (33.71)	Mean	44. 41	50.87	46.13	51.97
	SD	6.57	8.97	6.28	9.99
	Median	44.38	49.28	44.44	51.28
Trisyllables (37.08)	Mean	30.65	28.37	28.58	28.87
	SD	5.42	7.44	5.88	7.61
	Median	31.33	28.57	28.74	27.03
Four syllables (20.22)	Mean	19.21	17.24	18.59	14.26
	SD	3.65	4.61	1.70	4.84
	Median	19.28	15.73	19.05	13.73
Five syllables (5.62)	Mean	3.76	2.96	5.15	3.44
	SD	2.12	1.90	2.41	5.38
	Median	3.75	2.30	4.94	0.00
Six syllables (2.25)	Mean	1.18	0.10	0.85	0.45
	SD	1.01	0.35	1.29	1.00
	Median	1.20	0.00	0.00	0.00
Seven Syllables (1.12)	Mean	0.39	0.10	0.33	0.16
	SD	0.59	0.34	0.56	0.48
	Median	0.00	0.00	0.00	0.00

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment

Table 45

Mean, Median and Standard Deviation (SD) of Percentages of Various Syllable Shapes in Typically Developing Group and Clinical Groups

Syllable Shapes (Target %)		Group			
		TD (N=240)	TD (N=240)	TD (N=240)	TD (N=240)
VC (2.55)	Mean	3.06	3.74	2.79	4.06
	SD	0.72	1.00	0.38	1.15
	Median	2.99	3.48	2.63	4.17
CV (79.27)	Mean	76.02	76.98	75.91	73.34
	SD	2.32	6.06	1.71	3.93
	Median	76.24	76.26	75.68	72.65
V (3.64)	Mean	4.69	5.37	4.92	5.35
	SD	0.95	1.38	0.72	2.48
	Median	4.62	5.39	5.02	6.28
CVC (14.55)	Mean	15.83	15.43	16.11	16.92
	SD	1.64	1.85	1.28	2.67
	Median	15.62	15.92	15.95	17.13

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; VC= Vowel-Consonant; CV = Consonant-Vowel; V = Vowel; CVC = Consonant-Vowel-Consonant

One-Sample Wilcoxon Signed Rank Test was carried out to compare the percentage of each word shape and syllable shape produced by participants in each group with the corresponding target values. The results are presented in Table 46. There was a significant difference ($p < 0.05$) for all the word shapes and syllable shapes compared to the corresponding targets in the typically developing group. On the other hand, differences were observed to be significant for few of the word and syllable shapes in the clinical groups. There were significant differences ($p < 0.05$) for all the word shapes except for four syllables in SSD group, five syllables in SLI group and four, five and six syllables in the group at risk for dyslexia ($p > 0.05$). A significant difference was obtained in the percentage of polysyllables produced in comparison with the target in both the typically developing and each of the clinical group. Similarly, significant differences ($p < 0.05$) were observed for all the syllable shapes except for VC in the group at risk for dyslexia, CV and CVC in the SSD group and, V and CVC in the SLI group ($p > 0.05$).

Table 46

Results of One-Sample Wilcoxon Signed Rank Test for Word and Syllable Shapes

Word/Syllable shape (in percentage)	Group			
	TD (N=240)	SSD (N=11)	ARD (N=7)	SLI (N=9)
Bisyllables	S	S	S	S
Trisyllables	S	S	S	S
Four syllables	S	NS	NS	S
Five syllables	S	S	NS	NS
Six syllables	S	S	NS	S
Seven Syllables	S	S	S	S
VC	S	S	NS	S
CV	S	NS	S	S
V	S	S	S	NS
CVC	S	NS	S	NS

Note: S = Significant ($p < 0.05$), NS = Not significant; TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; VC= Vowel-Consonant; CV = Consonant-Vowel; V = Vowel; CVC = Consonant-Vowel-Consonant

C. Rapid Automatized Naming Test

The mean, standard deviation and median of the average time taken by participants in the typically developing group and clinical groups (children with SSD, children at risk for dyslexia and children with SLI) in each of the three RAN tests, namely RAN Nouns, RAN Verbs and RAN Size are presented in Table 47. It is observed that the time taken by participants in the clinical groups is greater than that of the typically developing group for RAN Nouns and RAN Size. On the other hand, the time taken for RAN Verbs was similar in the typically developing group and at risk for dyslexia group whereas it was greater in the SSD and SLI groups. Among the clinical groups, children at risk for dyslexia performed the RAN tests in lesser time compared to children with SSD, who in turn took lesser time compared to children with SLI.

Among the three RAN tests, the mean time taken was least for RAN Size followed by RAN Nouns and RAN Verbs in all the groups.

Table 47

Mean, Median and Standard Deviation (SD) of the Average Time Taken (in seconds) by Typically Developing Group and Clinical Groups on the Three RAN Tests

Subsection		Group			
		TD (N=240)	SSD (N=11)	ARD (N=7)	SLI (N=9)
RAN Nouns	Mean	99.98	108.42	105.71	124.00
	SD	16.11	24.09	12.89	29.87
	Median	101.00	110. 66	106.00	122.66
RAN Verbs	Mean	117.19	136.42	116.80	150.08
	SD	14.72	25.00	7.67	26.35
	Median	117.00	128.66	117.33	155.50
RAN Size	Mean	70.60	79.15	73.23	96.25
	SD	14.03	17.54	6.39	21.80
	Median	68.50	78.66	72.33	95.33

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; RAN = Rapid Automatized Naming

Kruskal Wallis H test revealed significant group effect for all the three RAN tests - RAN Nouns [$\chi^2(3) = 11.044$, $p < 0.05$], RAN Verbs [$\chi^2(3) = 19.061$, $p < 0.01$] and RAN Size [$\chi^2(3) = 17.457$, $p < 0.01$]. Mann-Whitney U test was run subsequently and the results of pairwise comparisons are given in Table 48.

Table 48

Results of Pairwise Comparisons using Mann-Whitney U Test for RAN tests

	|Z|		
	RAN Nouns	RAN Verbs	RAN Size
TD - SSD	1.210	2.803*	1.591
TD - SLI	2.987*	3.425*	3.823*
TD - ARD	1.108	0.003	0.864
SSD - SLI	0.912	0.991	2.015*
SSD - ARD	0.136	2.084*	0.498
SLI - ARD	1.697	2.375*	2.705*

*Note: * - p < 0.05; TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; RAN = Rapid Automatized Naming*

From table 48, it is observed that a significant difference in RAN Nouns was observed only between typically developing group and SLI group but not for any other groups. Similarly, only the SLI group differed from all other groups in RAN Size test. On the other hand, participants in the SSD and SLI groups differed significantly from both the typically developing and at risk for dyslexia groups in RAN Verbs.

Children with Childhood Apraxia of Speech (CAS)

The scores obtained by children with CAS in various subsections of the test battery are given in the Table 49. Of the three participants with CAS, only one participant in the age group of >4;0 - ≤4;6 years could complete all subsections of the test battery. The participant in the age group of >3;0 - ≤3;6 years could only complete the RAN Nouns and RAN Size tests, whereas participant in the age group of >3;6 - ≤4;0 years could complete the RAN tests and the Sentence Imitation Test. In general, the scores obtained by children with CAS in various subsections of the test battery were poorer than the corresponding mean scores of the expressive language age matched typically developing participants.

Table 49

Scores Obtained by the Three Participants in the CAS group in Various Subsections of the Test Battery

Subsection		Age Group (in years)		
		Participant 1 (>3;0 - ≤3;6)	Participant 2 (>3;6 - ≤4;0)	Participant 3 (>4;0 - ≤4;6)
Receptive Picture Vocabulary Test		30	32	33
Articulation Judgment	Vowels			50.33
	Consonants			51.00
Articulation Correction	Vowels			92.00
	Consonants			86.00
Sentence Imitation – Word Shapes	Bisyllables		43.00	50.00
	Trisyllables		2.00	19.0
	Four syllables		2.00	5.00
	Five syllables		1.00	4.00
	Six syllables		0.00	0.00
	Seven Syllables		0.00	0.00
	Total words		48.00	80.00
Sentence Imitation – Syllable Shapes	VC		4.00	7.00
	CV		80.00	146.00
	V		9.00	14.00
	CVC		12.00	32.00
	Total syllables		105.00	199.00
RAN	Nouns	165.67	141.67	89.33
	Verbs		184.00	157.67
	Size	144.00	127.33	65.67

Note: Shaded boxes indicate tests that the respective participant was unable to perform

3. Performance Profiles of Clinical Groups

An attempt was made to profile the performance of participants in the various clinical groups on different subsections of the test battery in comparison with that of typically developing participants matched for expressive language age. The measures considered included the average time taken (in seconds) to perform each of the three RAN tests and the median scores (in percentage) obtained in other subsections of the test battery (Articulation Judgment Test for Vowels and Consonants, Articulation Correction Test for Vowels and Consonants and Sentence Imitation Test). Figures 19 to 22 depict the group profiles of participants in each of the clinical groups in the age range of >3;0 - <u><</u>3;6, >3;6 - <u><</u>4;0, >4;0 - <u><</u>4;6 and >4;6 - <u><</u>5;0 years respectively for various subsections of the test battery.

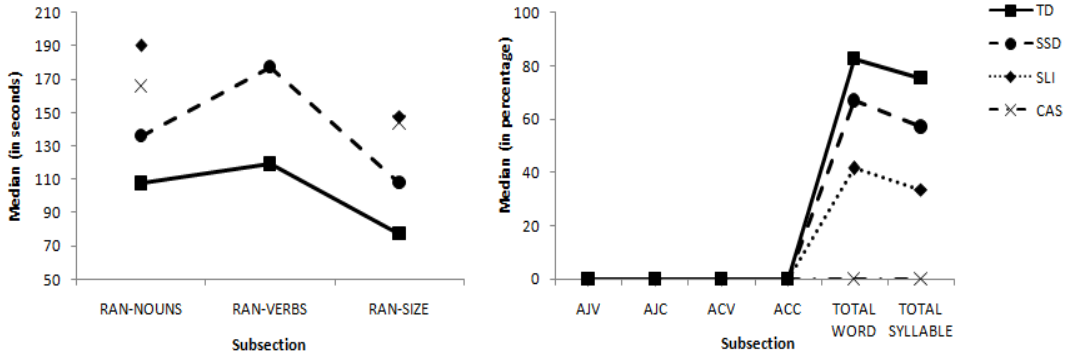


Figure 19. Profile of Participants in the Typically Developing Group and Clinical Groups in the age group of >3;0 - ≤3;6 years.

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; RAN = Rapid Automatized Naming; AJV = Articulation Judgment for Vowels; AJC = Articulation Judgment for Consonants; ACV = Articulation Correction for Vowels; ACC = Articulation Correction for Consonants

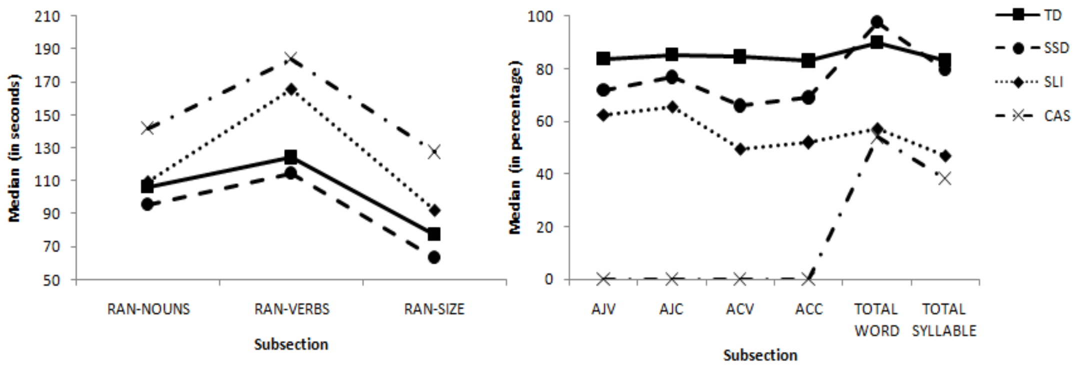


Figure 20. Profile of Participants in the Typically Developing Group and Clinical Groups in the age group of >3;6 - ≤4;0 years.

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; RAN = Rapid Automatized Naming; AJV = Articulation Judgment for Vowels; AJC = Articulation Judgment for Consonants; ACV = Articulation Correction for Vowels; ACC = Articulation Correction for Consonants

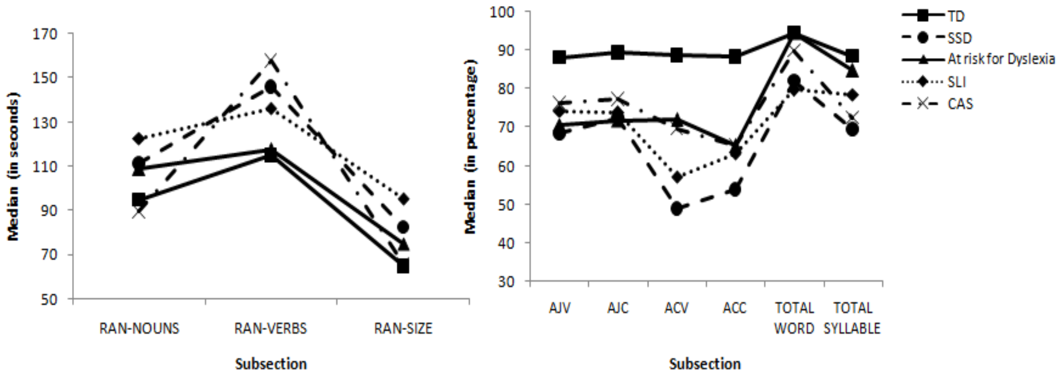


Figure 21. Profile of Participants in the Typically Developing Group and Clinical Groups in the Age Group of >4;0 - ≤4;6 years.

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; RAN = Rapid Automatized Naming; AJV = Articulation Judgment for Vowels; AJC = Articulation Judgment for Consonants; ACV = Articulation Correction for Vowels; ACC = Articulation Correction for Consonants

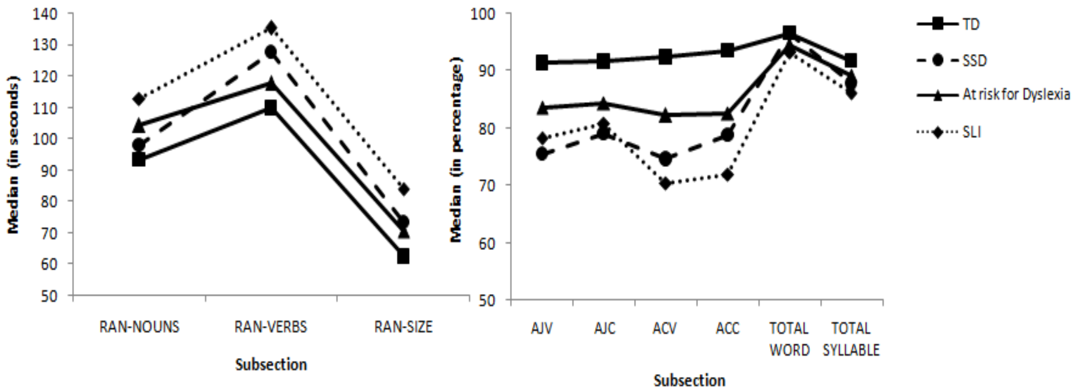


Figure 22. Profile of Participants in the Typically Developing Group and Clinical Groups in the age group of >4;6 - ≤5;0 years.

Note: TD = Typically Developing; SSD = Speech Sound Disorder; ARD = At Risk for Dyslexia; SLI = Specific Language Impairment; RAN = Rapid Automatized Naming; AJV = Articulation Judgment for Vowels; AJC = Articulation Judgment for Consonants; ACV = Articulation Correction for Vowels; ACC = Articulation Correction for Consonants

It is observed that the percentage scores of participants in the various clinical groups are poorer compared to the typically developing group. Although a delay is evident, the performance patterns of participants with different developmental disorders (SSD, SLI, at risk for dyslexia, CAS) are similar to that of the typically developing participants, particularly for RAN tests and Sentence Imitation test. A slightly different pattern was observed in the performance of participants in the clinical groups for Articulation Judgment and Articulation Correction tests. Further, performance of participants in different clinical groups was found to be similar in various subsections of the test battery.

4. Performance Profile of Individual Participants in the Clinical Group

In addition to the group profiles presented in Figures 19 to 22, the performance of individual participants in the clinical groups was also compared with that of the typically developing participants in the particular age group. This was done to obtain a better understanding of the performance of individual participants in the clinical groups. The clinical groups were heterogenous and the number of participants in each clinical group was unequal. Further, the distribution of participants of each clinical group in the four age ranges considered in the study varied widely with the number of participants ranging from 0 to 4 in different age groups. Figures 23 to 31 depict the performance of each participant in the clinical group in comparison with 95% confidence interval (CI) of the scores obtained by typically developing children in various subsections of the test battery.

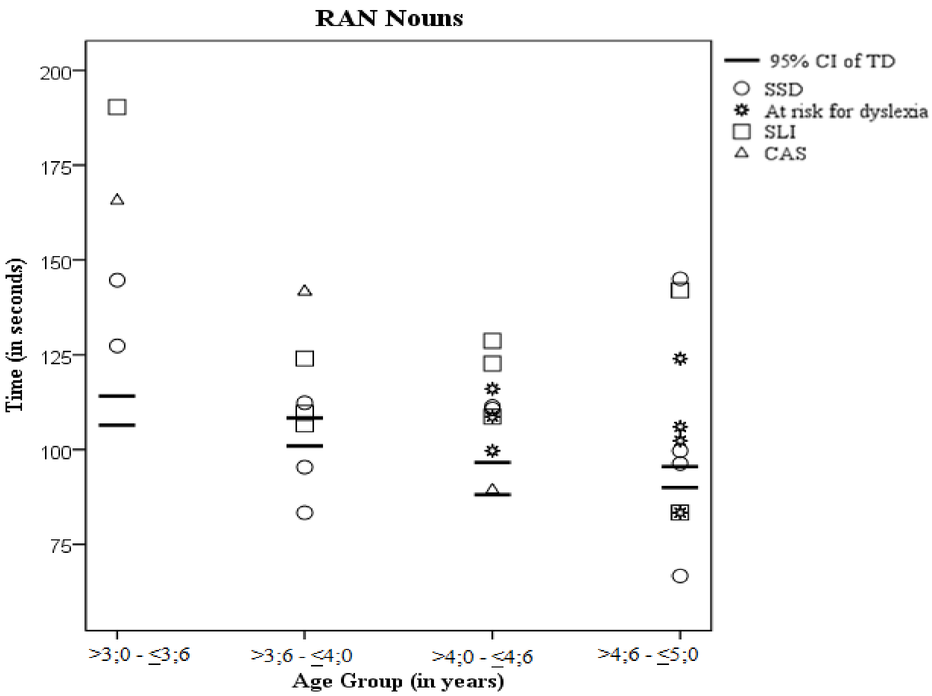


Figure 23. Performance of Participants in the Clinical Group on the Rapid Automatized Naming (RAN) Test for Nouns.

Note: CI = Confidence Interval; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; CAS = Childhood Apraxia of Speech

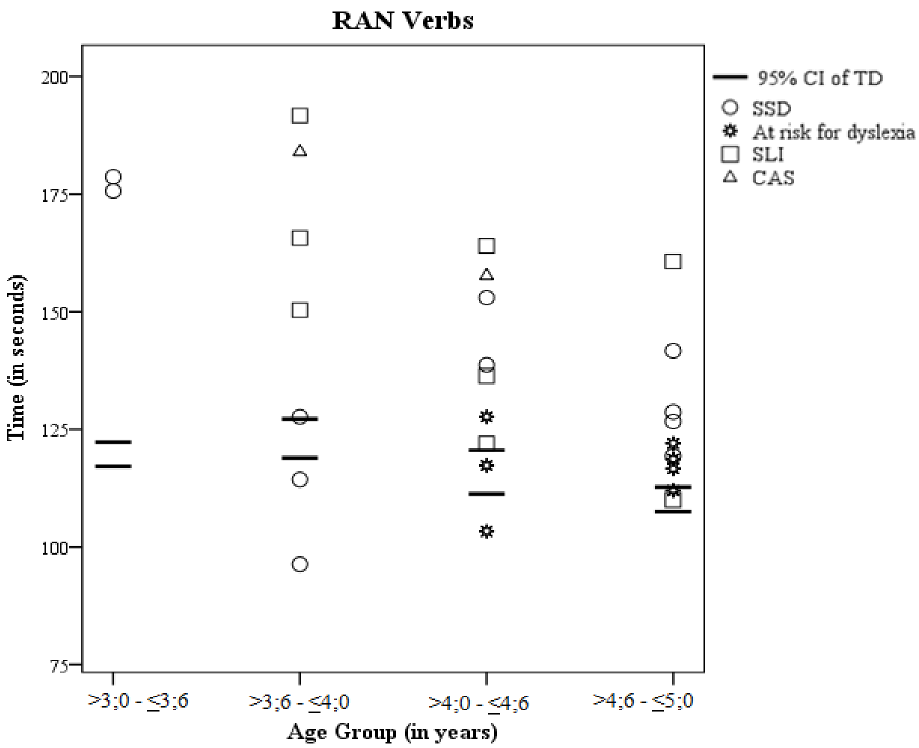


Figure 24. Performance of Participants in the Clinical Group on the Rapid Automatized Naming (RAN) Test for Verbs.

Note: CI = Confidence Interval; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; CAS = Childhood Apraxia of Speech

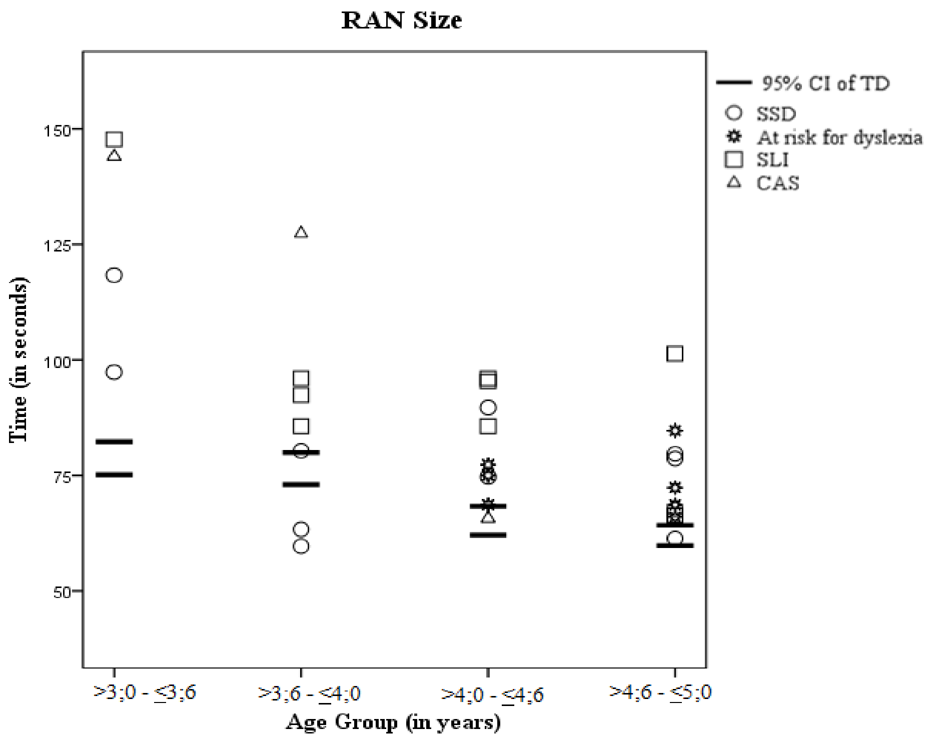


Figure 25. Performance of Participants in the Clinical Group on the Rapid Automatized Naming (RAN) Test for Size.

Note: CI = Confidence Interval; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; CAS = Childhood Apraxia of Speech

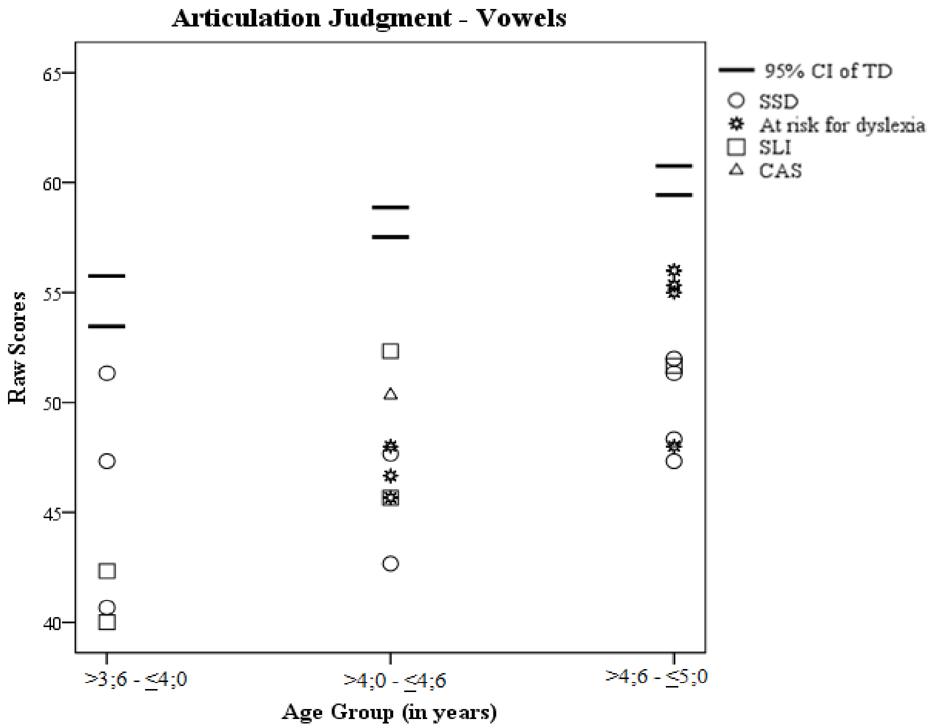


Figure 26. Performance of Participants in the Clinical Group on the Articulation Judgment Test for Vowels.

Note: CI = Confidence Interval; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; CAS = Childhood Apraxia of Speech

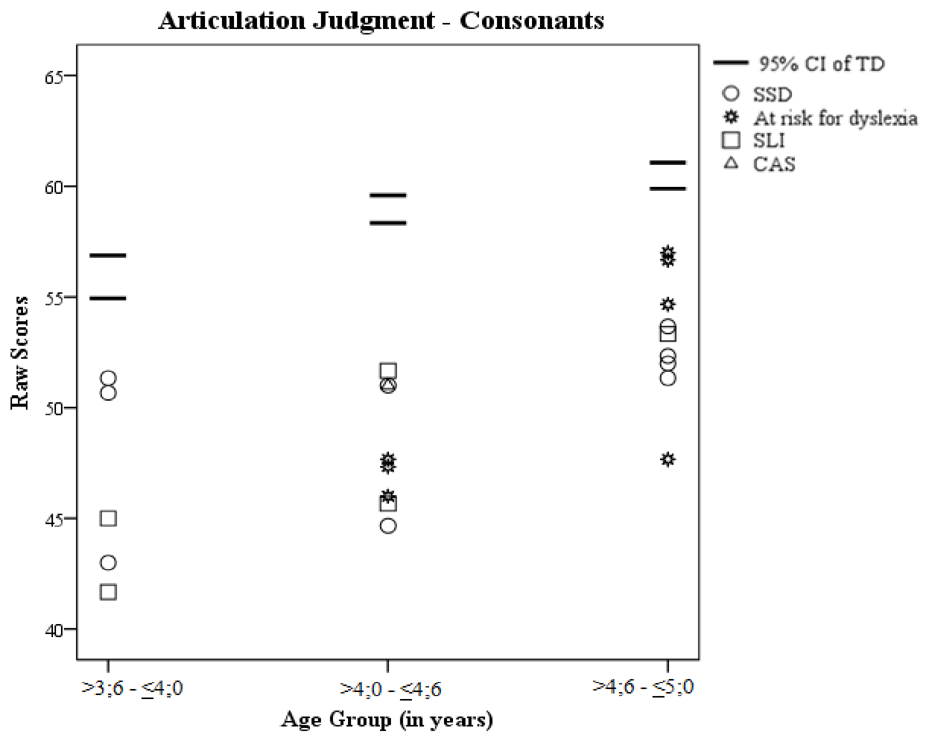


Figure 27. Performance of Participants in the Clinical Group on the Articulation Judgment Test for Consonants.

Note: CI = Confidence Interval; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; CAS = Childhood Apraxia of Speech

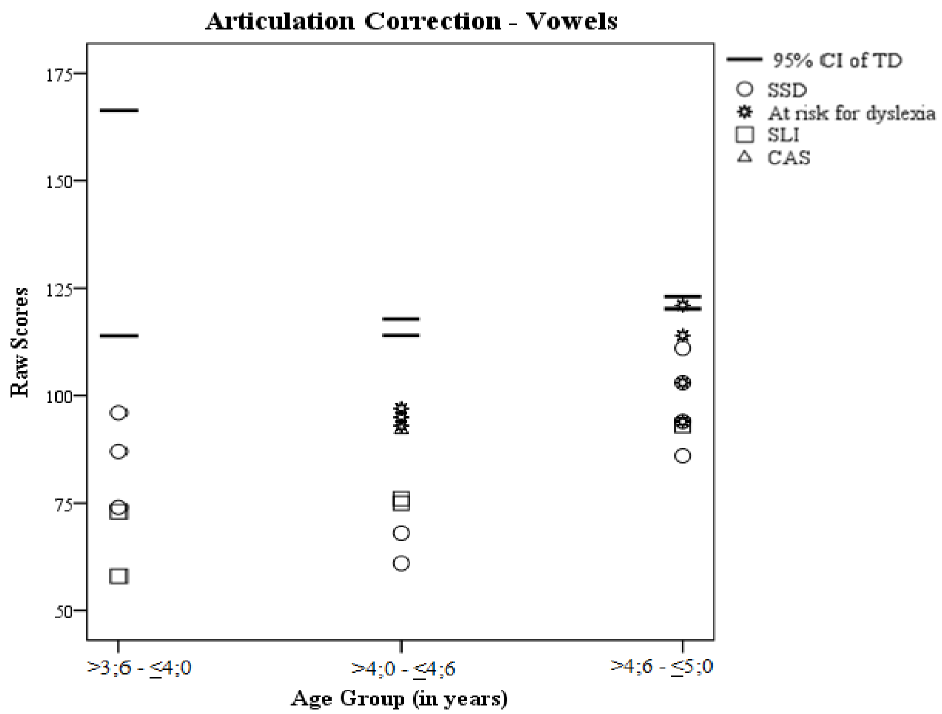


Figure 28. Performance of Participants in the Clinical Group on the Articulation Correction Test for Vowels.

Note: CI = Confidence Interval; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; CAS = Childhood Apraxia of Speech

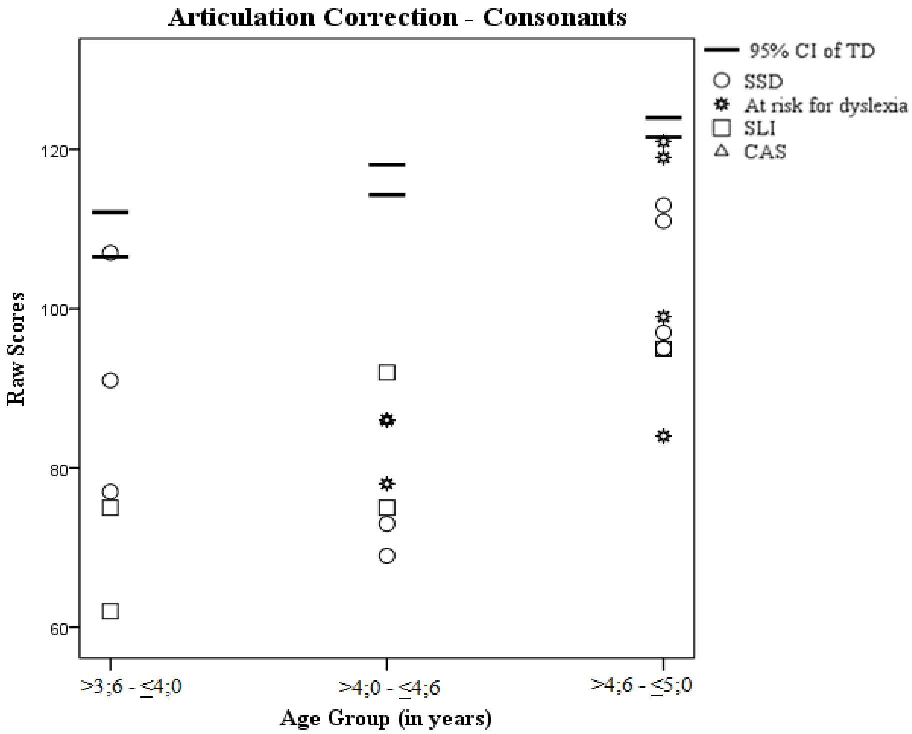


Figure 29. Performance of Participants in the Clinical Group on the Articulation Correction Test for Consonants.

Note: CI = Confidence Interval; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; CAS = Childhood Apraxia of Speech

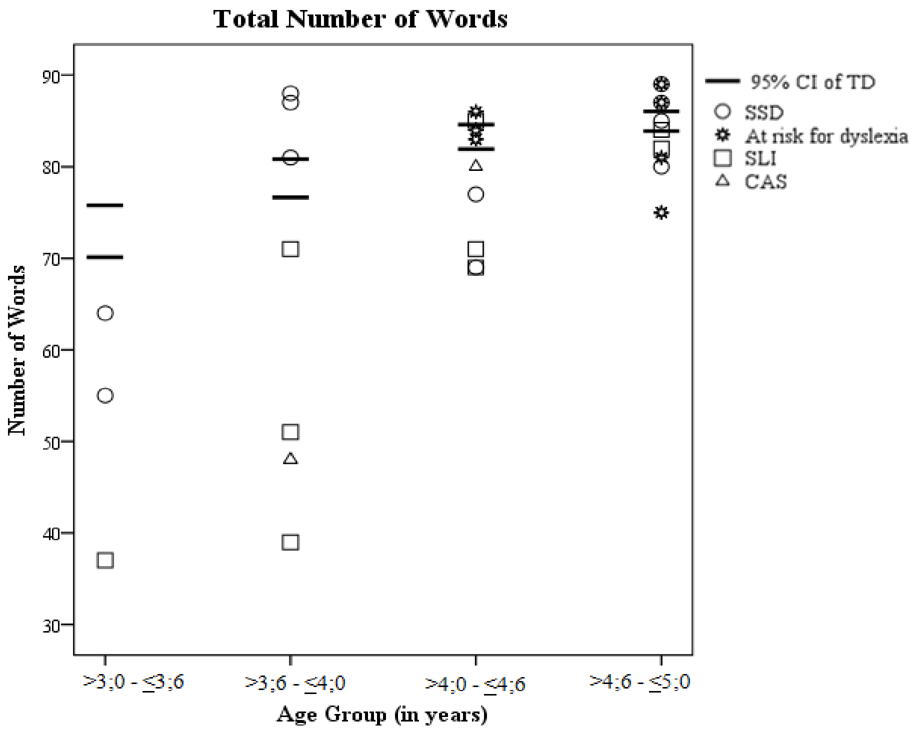


Figure 30. Total Number of Words Produced by Participants in the Clinical Group on the Sentence Imitation Test.

Note: CI = Confidence Interval; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; CAS = Childhood Apraxia of Speech

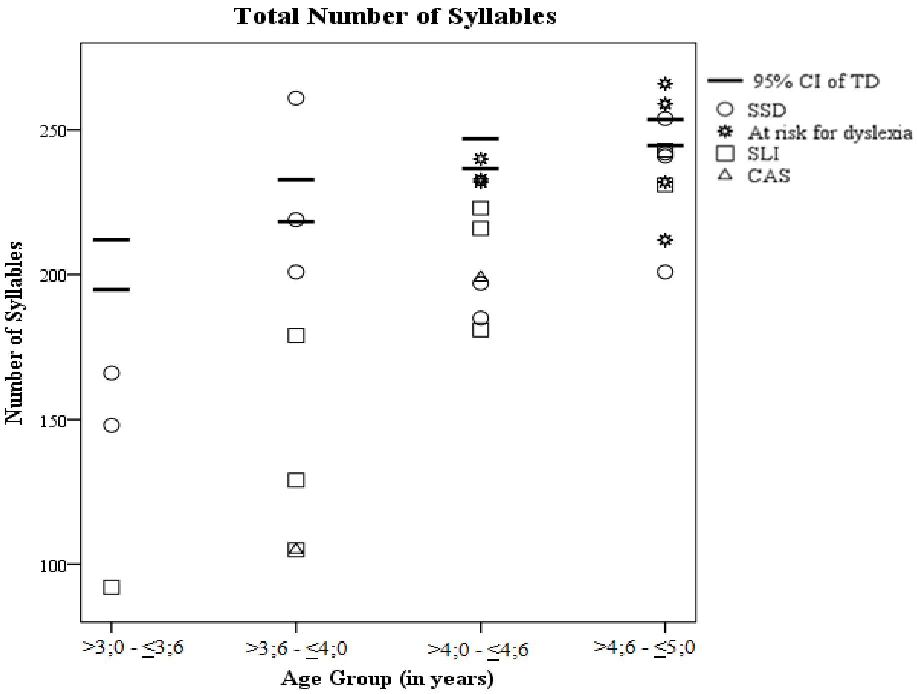


Figure 31. Total Number of Syllables Produced by Participants in the Clinical Group on the Sentence Imitation Test.

Note: CI = Confidence Interval; TD = Typically Developing; SSD = Speech Sound Disorder; SLI = Specific Language Impairment; CAS = Childhood Apraxia of Speech

From Figures 23 to 31, it is evident that in general, the performance of majority of the participants in the clinical groups was poorer compared to that of the typically developing group. However, it is also noteworthy to observe that the performance of few of the participants, albeit on certain subsections was either within the performance range of typically developing participants or in a few instances, better than the typically developing group. This trend was mainly observed in few participants diagnosed as SSD or at risk for dyslexia in certain age groups. Further, comparable or better performance of few participants in clinical groups than typically developing group was present for RAN tests and Sentence Imitation test but not in the Articulation Judgment and Articulation Correction tests for vowels and consonants.

The results presented under various sections are discussed in the next chapter.

DISCUSSION

A test battery was developed and administered on 240 Kannada speaking typically developing children in the age range of 3-5 years with the aim of assessing phonological representations in these children. These participants were further classified into four groups with an inter age interval of 6 months. The test battery was also administered on children with developmental disorders to check for its clinical utility. It was hypothesized that there is no significant effect of [1] gender [2] age and [3] stimuli on tasks tapping phonological representations in the test battery, viz., the Articulation Judgment Test for Vowels and Consonants, Articulation Correction Test for Vowels and Consonants, Sentence Imitation Test and Rapid Automatized Naming Test (Nouns, Verbs and Size) in Kannada speaking typical children between 3-5 years of age. It was further hypothesized that there is no difference between Kannada speaking typically developing children in the age range of 3-5 years and children with developmental disorders [Children with Speech Sound Disorder (SSD), Specific Language Impairment (SLI), Childhood Apraxia of Speech (CAS) and Children at risk for Dyslexia] matched for expressive language abilities in performance on the test battery for phonological representations.

The responses of the participants were analyzed to verify the specific objectives of the study and the results were presented accordingly in the previous chapter. The results revealed no significant difference between the performance of typically developing boys and girls in the four age groups considered in the study on all tasks of the test battery, thereby confirming hypothesis 1 of the study. However, there was a significant effect of age and stimuli, thus rejecting hypotheses 2 and 3 of the study.

Further, hypothesis 4 is rejected with the results indicating that the performance of children with various developmental disorders was significantly poorer compared to the typically developing groups for most of the tasks. In addition, comparison of the performance of different groups of children with developmental disorders yielded mixed findings.

The results presented in the previous chapter are discussed under the following sections.

I. Effect of Gender on the Performance of Typically Developing Participants in various Subsections of the Test Battery

There was no significant difference between the performance of Kannada speaking typically developing boys and girls in the age range of 3-5 years in any of the subsections of the test battery (Table 13). This finding is not in accordance with studies reporting differences between the two genders in phonological processing (Majeres, 1999, 2007; McGuiness, 1981; Moura et al., 2009; Pugh et al., 1997). Majeres (1999, 2007) reported superior performance of females in processing both pre-lexical and lexical information which were attributed to differences in the quality of phonological representations. McGuiness (1981) suggested that the cognitive differences between men and women could be a result of differences in the phonological and articulatory representations. These were further substantiated by the results of neuroimaging study by Pugh et al. (1997) who reported that there were greater activations in the right inferior frontal gyrus and the extrastriate regions during processing of phonological information in females compared to males.

Overall, small yet significant gender differences are reported in verbal abilities across a wide variety of tasks in favor of girls (Deaux, 1985; Halpern, 2013; Hyde & Linn, 1988; Maccoby & Jacklin, 1974). Several normative studies on the development of speech sounds have reported significant differences between boys and girls with a consensus that girls were faster than boys in the acquisition and mastery of speech sounds (Dodd et al., 2003). Specifically, Kenny and Prather (1986) investigated gender differences in the speech production abilities of 3-5 year old children and reported superior skills in girls compared to boys who had greater variability in their speech production. Although many studies reported gender differences in the acquisition of individual speech sounds, not many studies have investigated gender differences with respect to syllable structure or organization of the speech system. McCormack and Knighton (1996) reported differences between boys and girls aged two and a half years in their use of syllable structure processes that were attributed to differences in phonological representation of spoken words. Similarly, superiority of females in the use of polysyllabic word shapes are also reported (Shishira & Sreedevi, 2013; Sushma & Sreedevi, 2013).

There are also studies that have reported similar performance of boys and girls in terms of acquisition of speech sounds (Prathima & Sreedevi, 2009). Furthermore, gender differences are primarily reported in younger children whereas there are limited and inconsistent evidences during the preschool years (e.g.: Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Norrelgen et al., 2000). Roivainen (2011) reported gender differences in processing speed tasks where females were found to have an advantage in tasks involving digits and alphabets and males were faster on reaction time tasks and finger tapping. However, Wolff et al. (1983) documented a lack of difference between males and females in three Asian subgroups for rapid automatized naming tasks. Thus, there is no consensus in the literature with regard to the effect of gender on the development of phonological abilities. Although studies have reported differences between the two genders, the effect sizes of these were marginally low and accounted for minimal variance (Hyde & Linn, 1988).

The absence of a gender difference on tasks assessing phonological representations in this study may be attributed to the equal opportunities accorded to both boys and girls in the speech environment during the developmental years, particularly in the urban areas. *Thus, hypothesis 1 of the study is accepted i.e., there is no significant effect of gender on the performance of typically developing native speakers of Kannada in the age range of 3-5 years in any of the subsections of the test battery for phonological representations.*

II. Effect of Age and Stimuli on the Performance of Typically Developing Participants in various Subsections of the Test Battery

The effects of age and stimuli are discussed separately for each subsection of the test battery.

1. Articulation Judgment Test

Articulation Judgment Test was carried out for two types of stimuli, namely vowels and consonants. The participants in the age group of >3;0 - ≤3;6 years were unable to carry out the task whereas only 40% of the participants in the range of >3;6 - ≤4;0 years successfully completed the task. Participants who could not carry out these tasks mostly failed to understand the nature of the task while few refused to do the task as they perceived them to be difficult. Nevertheless, it indicates that articulation judgment tasks to detect mispronunciations of either vowel or consonant are suitable for children aged 4 years and above. This is supported by earlier studies on mispronunciation detection abilities in children. For example, Anthony et al. (2010) administered articulation judgment tests to examine the precision of phonological representations in children and the participants were mostly 4 year olds (Mean age - 4;6 years). Priya and Manjula (2016a) reported that by the age of 4 years, the phonological representations of children contain sufficient phonemic details of a single phoneme in the context of known words.

Results in the Articulation Judgment Test revealed significant effects of age and stimulus type in the performance of participants in the typically developing groups. The performance of participants in the Articulation Judgment Test increased with increase in age for both vowels and consonants (Table 15). The significant effect of age confirms the developmental trend in the articulation judgment abilities of both vowels and consonants in preschool children. Similar findings have been reported by studies conducted earlier (Fikkert, 2010; Kidd et al., 2015; Priya & Manjula, 2016a; Simon et al., 2014). Fikkert (2010) hypothesized that phonemic representations are abstract and undergo continuous changes during the developmental period. Based on vowel mispronunciation detection task in Dutch children aged 9-12 years, Simon et al. (2014) suggested that children have distinct phonological categories for phonemes in their native language by that age. They also reported that children had longer reaction times compared to adults in identifying vowel mispronunciations, implying that this ability develops throughout childhood. These findings suggest that the refinement of phonetic categories improve with increasing age, thereby supporting the "category definition hypothesis" (Walley & Flege, 1999) which states that phonetic categories are defined better with age. A developmental trend in the phonological representations indicates that lexical representations in children are not adult-like from the beginning, as postulated by the proponents of the generative theory of phonological development. Instead, there is maturation and continuing refinement of the initial representations that is influenced by the input to a large extent (Cleason et al., 2009).

Analyses with respect to the types of stimuli used in the articulation judgment test indicated a significant effect of stimuli on the performance of the typically developing participants. Comparison across vowels and consonants in the articulation judgment test revealed significant differences with higher scores for consonants in all age groups (Table 15). In other words, children were able to identify consonant mispronunciations better than vowel mispronunciations. These findings draw support from earlier studies by Nazzi (2005) and Priya and Manjula (2016a) who reported that mispronunciation detection tasks for vowels and consonants yield different results. The differences in performance for vowels and consonants could be the result of varied segmental features of the two categories of phonemes. Consonants and vowels have different acoustic and articulatory characteristics. Features of consonants are said to be categorically distinct from each other while vocalic features are not. In this study, vowel substitutions involved variations along the dimensions of tongue height and tongue advancement whereas consonants differed with respect to the place of articulation, manner of articulation, voicing or a combination of any or all of these features. A change in place of articulation of a consonant need not accompany changes in manner or voicing features. On the other hand, a change in vowel height may also bring about a small change in the vowel backness or vice versa (Mani &

Plunkett, 2007). The effects of mispronunciations are reported to vary with the number of mispronounced features (White et al., 2005). A similar effect is observed in this study where the number of features involved in consonant substitution was clearly greater than that of vowel substitution, thereby leading to a difference in the performance of the participants for vowels and consonants. Vowels are also reported to have a greater degree of normalization in speech perception compared to consonants due to relatively greater variability of vowels across speakers (Peterson & Barney, 1952). In addition, phonological categories for vowels are reported to be flexible and overlapping, thus rendering identification of vowel substitutions which are acoustically very close to the target vowels difficult (Simon et al., 2014). Few investigators have also reported that familiarity with the dialectal variations of a given language could result in overlap in the representations (Adank, van Hout, & van de Velde, 2007; Simon et al., 2014). Words, for which the substituting vowel can, in some dialects, be the phonetic realization of the target vowel phoneme, may therefore potentially be accepted by children as well as by adults. Although the participants of this study were native speakers of Mysuru dialect of Kannada language, they could have been familiar with other dialects of the language. These factors could further account for greater detection of consonant mispronunciations by typically developing preschool children compared to that of vowels.

When viewed in the context of phonological structure of Kannada language, it is intriguing to note that the basic phonological unit in Kannada, a language with alphasyllabary structure, is the syllable as opposed to phoneme which is the case in alphabetic languages like English. The orthographic system of Kannada also represents speech roughly at the level of syllable and all the phonemes in the unit are represented by the symbol in an embedded form. The base symbol represents the consonant while the vowel is represented using a diacritic which is physically connected to the base symbol. During the preschool years, the syllables and their corresponding symbols are taught to children as a whole, and the constituent parts of the syllable are not explicitly stated. Thus, the ability to detect mispronunciations of a single vowel or consonant which is an embedded component of the syllable indicates that the phonological representations are detailed at the level of individual phonemes even in semi-syllabic languages like Kannada. Kidd et al. (2015) assessed phonological representations in Cantonese-speaking Chinese children in the age range of 4-10 years using mispronunciation detection tasks and reported that fine grained segmented representations were developed in older children even in the absence of script-sound correspondence at the level of phoneme in Chinese orthography. The results in this study where participants were native speakers of Kannada but studied in schools with English as the medium of instruction is akin to the observations made by Kidd et al. (2015) in Cantonese-speaking Chinese children.

The error patterns in the response of typically developing participants were analyzed qualitatively and the results yielded some interesting features. While the error patterns for both vowels and consonants overlapped in participants groups of >4;0 - ≤4;6 years and >4;6 - ≤5;0 years, it was observed to be distinct in the age group of >3;6 - ≤4;0 years. The vowel errors were analyzed separately along two dimensions namely, tongue height and tongue advancement. The percentage of various error patterns decreased with increase in the age range of the participants (Tables 16 and 17). Further, the percentage of errors were found to decrease as the tongue height of substituted vowels moved from low or mid to high. Similarly, the percentage of errors decreased as the placement of the tongue for the substituted vowels moved from front to back. Further, the error percentage decreased with increase in distance between the target and substituted vowels (Figures 5 and 6).

Analogous to the error patterns for vowels, the percentage of various error patterns for consonants decreased with increase in the age range of the participants (Tables 18 to 20). The consonant errors were analyzed with respect to the place of articulation, manner of articulation and voicing. The maximum percentage of errors was observed when the palatal place of articulation was substituted for dental, whereas, substitution of stop for flap yielded the highest error percentage for the manner of articulation. With respect to voicing, substitution of unvoiced for voiced consonants resulted in greater error percentage in participants of all the three age groups (Figures 7 to 9).

The finding that young infants and toddlers are sensitive to mispronunciations of both familiar and unfamiliar words has been universally acknowledged (Bailey & Plunkett, 2002; Ballem & Plunkett, 2005; Mani & Plunkett, 2007; Swingley, 2007; Swingley & Aslin, 2000), and in these studies, researchers have claimed that there is sufficient phonological detail in the lexical representations of very young children. However, research conducted later has provided evidence that children's sensitivity to mispronunciations differ with respect to various segmental features. For example, Mani et al. (2008) reported better sensitivity in 18-months-old infants to changes in roundedness of vowels as compared to tongue height or tongue advancement. Similarly, sensitivity in 12-month-olds to variations in voicing characteristics was reported to be lesser than that of place and manner features of consonants (Mani & Plunkett, 2010a, Van der Feest, 2007). Furthermore, variations are also reported within the category of place and manners of articulation. Altvater-Mackensen et al. (2014) showed that 18- and 24-month-olds perceive changes in certain place and manner better than others. These observations supported and strengthened the notion that in addition to phonemic information of familiar words in the lexical representations, there is also encoding of fine-grained sub-phonemic information (Altvater-Mackensen & Mani, 2013, 2015; Mani & Plunkett, 2010b; White & Morgan, 2008). Sub-phonemic cues are utilized during mispronunciation detection tasks as such words are not a part of the existing lexicon of children, thereby involving resources in a bottom-up processing (Altvater-Mackensen & Mani, 2013, 2015). Altvater-Mackensen and Mani (2013, 2015) have reported that mispronunciations activated the correct form of target label in the lexicon and therefore, question the contribution of top-down lexical processing in mispronunciation detection tasks. Although these studies were based on investigations in infants and toddlers, similar observations were made in the current study where the participants were preschoolers in the age range of 3-5 years. Differences in the error percentages of substitution patterns for various dimensions of both vowels and consonants substantiate the earlier reports about utilization of both segmental and sub-segmental information associated with lexical representations in articulation judgment tests.

Furthermore, a parallel could be drawn between developmental trends in perception and production by extrapolating the literature available on acquisition of vowels and consonants. Existing literature on vowel acquisition in children have indicated that low central vowels are generally acquired earlier than the other types of vowels (Buhr, 1980; Donegan, 2013; Otomo & Stoel-Gammon, 1992; Sushma & Sreedevi, 2013;

Shishira & Sreedevi, 2013). Donegan (2013) reported that children produce height differences in vowels earlier compared to differences along the dimension of tongue advancement. With respect to tongue height, low vowels are produced earlier than mid and high vowels whereas, in terms of tongue advancement, central vowels are reported to precede development of front and back vowels (Selby et al., 2000; Shishira & Sreedevi, 2013; Sushma & Sreedevi, 2013).

Similarly, literature on development of consonants reveals that with respect to place of articulation, bilabials followed by dentals are among the earliest to be produced by children. With respect to the manners of articulation, stops are reported to precede development of nasals, glides and laterals in that order. Voiced sounds are reported to develop prior to their unvoiced counterparts. Retroflex, velar and glottal sounds are among the last reported to be acquired in terms of place whereas fricatives and affricates occur later among the various manners of articulation (Dyson & Paden, 1983; Hua & Dodd, 2000; Shishira & Sreedevi, 2013; Sushma & Sreedevi, 2013). Considering the error patterns exhibited by the participants in this study, it appears that any variations in the phonemes that are acquired early are less likely to be perceived on Articulation Judgment Test, particularly when the variations are limited to a single feature. However, further studies are required to verify this stand while considering the effects of systematic manipulation of the stimuli.

2. Articulation Correction Test

Articulation Correction Test for vowels and consonants were found to be suitable for children in the age group of >3;6 - $\leq$4;0 years and above. In this task, the participants were required to first judge the accuracy in articulation of the stimulus that was presented through auditory mode with reference to the picture stimulus that was presented simultaneously. Whenever the accuracy of articulation was judged as incorrect, the participants were asked to produce the correct form of the same. Results indicated a significant effect of age on the performance of participants in the Articulation Correction Test but there were no significant effects of gender and stimulus types.

The scores obtained by participants in the Articulation Correction Test for both vowels and consonants increased with increase in age, thereby signifying a developmental trend in the ability of preschool children to identify and correct mispronunciations in words (Table 21). These findings are in parallel to that reported by Elbro et al. (1998) and Foy and Mann (2001). Foy and Mann (2001) studied the articulation correction abilities (termed as phonological distinction task) in children between the ages of 4 to 6 years and reported that the skills improved with age. This improvement was attributed to a shift in the nature of phonological representations of speech from holistic to segmental level as a consequence of exposure to literacy in the early school years. Learning to read helps internalize the alphabetic code which in turn would result in children performing a discrete analysis at phoneme level (Ehri & Wilce, 1980; Metsala, 1997a; McBride-Chang & Ho, 2000). Elbro et al. (1998) reported that the performance of children in kindergarten in the articulation correction task predicted the growth of phonemic awareness and thus the reading abilities of the participants in second grade. This was attributed to refinement of accuracy of phonological representations in children during their preschool years. Recently, investigators have also shown that training children in correcting mispronunciations of spoken words along with the corresponding word meanings results in generalized gains on learning to read (Dyson, Best, Solity, & Hulme, 2017; Kearns, Rogers, Koriakin, & Ghanem, 2016).

Although a significant age effect was present, there was no significant difference in the performance of participants in the Articulation Correction Test for the two types of stimuli used; vowels and consonants. There is no reported literature comparing the performance of typically developing children on articulation correction tests for vowels and consonants. It may be recalled that typically developing participants performed articulation judgment tests differently for vowels and consonants. Given that articulation correction tests encompass articulation judgment and the same set of stimuli were used for the two tasks, the absence of a difference between vowels and consonants could be attributed to the nature of the task and the procedure used to score the task. Articulation correction tests involved judgment of the stimulus followed by correct production of mispronounced stimuli. In the articulation judgment tests, it was found that consonant mispronunciations were detected better than vowel mispronunciations. This means that the opportunity to correct errors were greater for consonants as compared to vowels. However, as indicative by scores for correct production of vowels and consonants, scores obtained for target vowels were greater than that of consonants in the lower age groups although the differences were statistically not significant (Table 22 & Figure 10). Taking these two aspects into consideration, the differences observed in articulation correction tests between vowels and consonants could have been neutralized. This trend is further supported by studies which reported that most of the vowels in Kannada language are achieved in typically developing children by the age of 3 years whereas consonants are achieved by the age of 4 years and above (Prathima & Sreedevi, 2009; Deepa & Savithri, 2010). However, consonant clusters in Kannada are reported to continue developing until the age of 6 years (Deepa & Savithri, 2010). As the stimuli used in the present study were clusters, the errors noted in the production of consonants could be developmental in nature. On the whole, these can be considered as additional support for the findings of the study suggesting that phonological representations show a developmental trend in preschool years and that Articulation Correction Test is a sensitive measure to tap phonological representations.

Goswami (2012) conjectured that phonological representations are sufficiently developed in children by around 3-4 years of age with adequate detailing from the perspective of both linguistic and cognitive levels of phonological representations. This facilitates accurate comprehension and production of speech sounds in the correct order in words. Taken together, the results of Articulation Judgment and Articulation Correction Tests support the findings of Goswami (2012).

3. Sentence Imitation Test

A total of 20 sentences developed by the investigator were audio recorded and presented to the participants for imitation. The responses of the participants were analyzed in terms of various word shapes and syllable shapes. Results revealed a significant effect of age on the total scores obtained on word shapes and syllable shapes. This indicates a developmental trend in the phonotactic abilities of typically developing children during their preschool years. Similar findings were reported by Rupela and Manjula (2006) and Priya and Manjula (2016b). The study by Rupela and Manjula (2006) was based on the analyses of conversation samples in 0-5 year old native speakers of Kannada whereas Priya and Manjula (2016b) reported similar findings based on sentence imitation task with a smaller number of participants.

A developmental trend was evident for trisyllables and polysyllables (with the exception of six syllables) with regard to word shapes, but there was no significant difference between age groups for bisyllables (Table 23). On detailed analyses of the imitated utterances, it was observed that the lengthier word shapes were reduced most often to bisyllables which have a high frequency of occurrence in Kannada. This was particularly evident in participants in the younger age groups who reduced the tri and polysyllabic utterances to bisyllables presumably due to ease of production of bisyllables.

A significant effect of age was obtained for CV and CVC but not for V and VC with respect to the syllable shapes (Table 24). The lack of effect of age for V and VC structures may be attributed to the lower occurrences of V and VC as compared to CV and CVC in Kannada language in general which also reflected in the target sentences used in this test. Rupela and Manjula (2006) reported that the frequency of occurrence of syllable shape V was very low in typically developing Kannada speaking children. Thus, the findings of this study appear to be in consonance with that of Rupela and Manjula (2006) and Priya and Manjula (2016b) who reported similar findings.

The findings of Priya and Manjula (2016b) were based on analyses of a smaller data set of the present study. The stimuli used and the patterns of response analyses were the same as in the present study. It was observed that children who were native speakers of Kannada in the age group of >3;0 - ≤3;6 years were significantly different from all other groups of participants (study included children in the age range of 3-5 years) for all words shapes and syllable shapes, and hence it was concluded that children begin to gain mastery over most of the word shapes and syllable shapes permitted by the phonotactic rules of Kannada language after the age of 3;6 years. Similar results were obtained in this study, thereby confirming the findings obtained in the earlier study (Priya & Manjula, 2016b) which included a smaller number of participants. The observation that the findings in the present study are due to inadequate phonological representations in young children or an inadequate access to the same is well supported. Poorly developed or insufficient access to phonological representations could render retention, and therefore, imitation of accurate word and syllable shapes of the target sentences difficult. Sentence imitation may therefore be considered as a valuable task in the assessment of phonotactic abilities in preschool children, which in turn helps in understanding the underlying phonological representations.

The percentages of various word shapes and syllable shapes were also compared to the corresponding targets in each of the four age groups, in addition to the comparison of actual scores obtained by participants across age groups. It was observed that the percentages of various word and syllable shapes were similar for participants in both the younger and older age groups despite decreased overall scores of participants of the younger age groups (Tables 27 and 28). Children in the younger age groups produced polysyllabic utterances in the sentence imitation test which consisted of five, six and seven syllables. However, the percentage of polysyllables was lesser compared to the older participants considered in the study.

There were few interesting findings observed in the study with respect to the percentage of word and syllable shapes. The percentage of bisyllables in the imitated utterances was found to exceed the target bisyllables in the stimuli (Figure 11). This was true for participants of all age groups, particularly the younger age groups. These findings support the hypothesis that the phonological representations for words of increased length are not completely developed until 5 years of age in typically developing children (Priya & Manjula, 2016b). Similarly, among the syllable shapes considered in the study, the percentage of CV syllables was higher in all the age groups (Figure 12). This was expected as it is well known that CV syllables are the most commonly and frequently occurring syllable shape in Kannada, The higher percentage of CV is likely to have reduced the percentage of VC and CVC syllables in the sample.

Therefore, it may be speculated that the phonological representations, as well as the access to the same, may be well developed for the frequently occurring word and syllable shapes in the language concerned while the representations for word and syllable shapes occurring at lower frequencies may still be in the process of development. The findings of this study further strengthen existing studies in the literature supporting the contribution of phonological representations in sentence recall (Melby-Lervag & Hulme, 2010; Park, 2002; Priya & Manjula, 2016b; Rummer & Engelkamp, 2003; Schweppe et al., 2011). It may be noted that the method used for the analyses of responses of imitated sentences adopted in the current study varied from the earlier reported studies on sentence imitation. Yet, the findings of a significant age effect in the development of phonotactic patterns and thereby the phonological representations in children substantiate its role in sentence imitation.

Further, these findings offer support in rejecting the ‘Conceptual Regeneration Hypothesis’ (Potter & Lombardi, 1990), according to which, verbatim sentence recall task only involves conceptual and lexical processes and there is no contribution of any phonological information. The claims made by the proponents of the Conceptual Regeneration Hypothesis were refuted by other studies carried out on immediate sentence recall in both neurotypical individuals (Katz, 1998; Park, 2002; Rummer & Engelkamp, 2001) and those with brain damage (Hanten & Martin, 2000; Martin et al., 1994). On the whole, the results of this study confirm the contribution of phonological representations in Sentence Imitation Test in typically developing preschoolers.

Although the role of phonological representations in sentence imitation is well substantiated in the current study, the contribution of semantic representations cannot be undermined, which was particularly evident when qualitative analyses of the imitated utterances were carried out. The use of equivalent English words instead of the target Kannada nouns by the participants and also instances of semantic substitutions used by the participants point to the involvement of semantic representations in the sentence imitation task. Taken together, the findings of this study implicate the role of both phonological and semantic representations in immediate sentence imitation. This is in consonance with similar reports in the literature on short-term sentence recall (Anderson, 1971; Hayes-Roth & Hayes-Roth, 1977; Moeser, 1974; Park, 2002).

The poor access to phonological representations of target words in the sentence might also have led the participants to substitute an alternate word in the same language in order to complete the sentence without affecting the syntactic structure. Thus semantic substitutions may have occurred as a consequence of poorly developed phonological representations of the target words and/or access to the same. In addition to semantic substitutions, use of equivalent English words instead of the target Kannada nouns may be attributed to the fact that the participants of the study were native Kannada speakers studying in schools with English as the medium of instruction. The bilingual exposure could have facilitated the substitution of Kannada target nouns by English equivalents. Such an explanation is also provided by Prasad and Rao (2011), who studied the phenomenon of code-switching and borrowing in native Kannada speakers and reported that children often switched languages (from Kannada to English) for particular word class like nouns – names of vegetables (shirt), clothes (shirt), profession (doctor) etc. Consistent and frequent use of the English words, particularly nouns, in routine conversations could have triggered code-switching and borrowing in the participants of the present study in order to complete the sentence imitation task. This also explains the presence of monosyllables in the imitated samples which were otherwise absent in the target stimuli. Substitution of Kannada words by English equivalents occasionally resulted in the production of monosyllables which are otherwise rare in Kannada language (Hiremath, 1980; Nag-Arulmani et al., 2003). The proportion of monosyllabic words in English is far greater than bi- and multisyllabic words (Caravolas, 1993) whereas the converse is true for Kannada.

4. Rapid Automatized Naming Tests

RAN was carried out for three types of stimuli – Nouns, Verbs and Size. The participants were asked to name each picture stimuli presented in an array of 50 items in a serial order as fast and as accurately as possible. The time taken in seconds to rapidly name each array was noted down separately for individual participants and compared across age groups and stimulus types. Results revealed a significant effect of age on the performance of typically developing participants on each of the three tasks – RAN Nouns, RAN Verbs and RAN Size. However, the difference was not significant in some of the adjacent age groups especially for RAN Verbs. The stimulus used for the RAN tasks also had a significant effect on the performance of participants in each of the age groups considered in the study. The performance was found to be better for RAN size followed by RAN Nouns and RAN Verbs (Table 30).

A significant effect of age on RAN tasks indicates a developmental trend in the ability of preschool children to rapidly name picture stimuli. These findings are supported by other studies which reported a developmental trend in the performance on RAN tasks (Anthony et al., 2010; Araujo et al., 2016; Cohen et al., 1999; Khurana, 2011; Kuppuraj & Shanbal, 2009; Ranjini & Rajasudhakar, 2011). With the exception of Anthony et al. (2010) and Khurana (2011), the other investigators measured rapid naming abilities in relatively older children (5 years and above) and the stimuli used included letters, objects, colors and digits. Khurana (2011) compared RAN skills in preschool children who were Kannada speaking English Language Learners. RAN for objects and size were studied by Khurana (2011) who reported a significant developmental trend in the performance of children from pre-kindergarten (PKG) to lower kindergarten (LKG) but not from LKG to upper kindergarten (UKG). The reason was attributed to the challenging nature of the task for younger children compared to their older counterparts that resulted in a significant difference in the performance between PKG and LKG children. In this study too, there were no differences observed in the performance of participants in the adjacent age groups. It is reasoned that the similar performance of participant groups with an inter age interval of 6 months could be due to the nature of the task and it is probable that differences in performance could have emerged if the inter age interval between groups of participants was more than 6 months. This is further supported by the findings of Biddappa et al. (2016) who studied rapid naming abilities for nouns and verbs in children studying in UKG and Grade 1. The authors did not report any differences in the performance of children in the two groups on RAN tasks. However, it may be noted that the participants were asked to rapidly name the stimuli in English in the study by Biddappa et al. (2016) whereas the language of interest in the current study was Kannada. Ranjini and Rajasudhakar (2011) investigated RAN in Kannada for objects, letters, colors and digits in 6-8 year old Kannada speaking children. Although results revealed a significant developmental trend in the performance of participants on RAN task, differences were not observed across participant groups with an inter age interval of 6 months for most of the tasks.

The findings in the present study are supported by developmental studies on RAN reported in the literature. While RAN tasks are generally carried out for objects, colors, digits and letters, the present study used nouns, verbs and size as the stimuli for RAN task in order to study the access by participants to stored phonological representations. However, it is to be noted that there are no studies that have specifically used stimulus as in the present study with the exception of Biddappa et al. (2016) in which nouns and verbs were used as stimuli. Using nouns, verbs and size as the stimuli for RAN task, a significant developmental trend was observed in the RAN abilities in participants in the age range of 3-5 years.

The results of RAN tasks also revealed a significant effect of the type of stimuli. Typically developing participants in each of the age groups performed RAN Size task with greater speed, followed by RAN Nouns and RAN Verbs. These findings can be attributed to the inherent nature of the stimulus and the expected response. RAN Size task required the participants to only say either /doɖɖadu/ 'big' or /ʧikkadu/ 'small' for each of the items in the stimulus array. On the other hand, RAN Nouns required the participants to produce the name of each item in the array whereas RAN Verbs required them to name the action depicted in the pictures. Understandably, the length of utterance expected for RAN Nouns is smaller compared to RAN Verbs particularly in the case of Kannada language. These findings are in consonance with Biddappa et al. (2016) who reported that RAN Nouns are performed with greater speed than RAN Verbs. This could also be due to several other factors. Firstly, among the various classes of words acquired by children during the developmental years, nouns are acquired before verbs (Gentner, 1982; Golinkoff & Hirsh-Pasek, 2008). Nouns are also reported to be more predominant than other word classes in both receptive and expressive vocabularies of children (Bornstein et al., 2004; Umek, Fekonja-Peklaj, & Podlesek, 2013). The precedence of nouns before verbs during language acquisition and its extensive usage during the developmental years of children could result in faster and more automatic processing of nouns as compared to verbs. In addition, studies comparing the processing of nouns and verbs have reported that the two classes of words are processed differently and verb processing is difficult than that of nouns. Matzig, Druks, Masterson, & Vigliocco (2009) attributed difficulty in verb processing to greater complexity in the semantic organization and morphological arrangement of verbs, variations in the argument structures in a sentence along with diminished imageability of verbs.

The nature of rapid naming tests entails that the stimuli used are in the receptive vocabulary of the individual. On this account, RAN tests are considered as an effective measure of access to extant phonological representations (Anthony et al., 2011). RAN being a measure of efficient access to phonological representations or retrieval of the same, a developmental trend in the performance of participants on RAN tests could be a reflection of impoverished phonological representations in younger children in contrast to their older counterparts (Bowey et al., 2005; Heikkila, 2015; Kibby et al., 2014; Pennington et al., 2001; Ramus, 2014; Ramus & Szenkovits, 2008; Savage et al., 2007; Torgesen, et al., 1997; Vaessen et al., 2009; Vellutino et al., 2004; Wagner et al., 1997). This implies that the phonological representations are in the process of development during the preschool years. Similarly, differences in performance for different stimuli used in RAN tests can be taken as support for the developing phonological representations for words of different length and complexity. This supports that what is being measured is accessibility of phonological representations rather than whether a participant has phonological representations for the target words, which is also known as vocabulary size.

In view of the above aspects, Hypotheses 2 and 3 posited in the study stating that there is no significant effect of age and stimuli respectively on the performance of typically developing native speakers of Kannada in the age range of 3-5 years on tasks assessing phonological representations are rejected. Tasks such as Articulation Judgment for Vowels and Consonants, Articulation Correction of Vowels and Consonants, Sentence Imitation and Rapid Automatized Naming (Nouns, Verbs and Size) show a developmental pattern from 3-5 years of age. Hence, the findings of the study can be taken as support for the emergent view of development of phonological representations which states that phonological representations gradually become accurate and segmented (Ainsworth et al., 2016).

III. Comparison between the Performance of Typically Developing Group and Clinical Group in various Subsections of the Test Battery

The test battery for phonological representations was administered on a small group of children with developmental disorders to check for the clinical utility of the test battery. A small number of children with Speech Sound Disorder (SSD), Specific Language Impairment (SLI), Childhood Apraxia of Speech (CAS) and children at risk for dyslexia whose expressive language age was in the range of 3-5 years were included in the study. Overall, results indicated that children with developmental disorders performed poorer than typically developing children matched for expressive language age on tasks assessing phonological representations (Tables 33, 34, 36, 39, 40, 45 & Figure 13). Among the children with developmental disorders, children at risk for dyslexia performed better on most tasks followed by children with SSD and SLI, although these differences were not always statistically significant.

The poor performance of children with developmental disorders on various tasks assessing phonological representations is in consonance with similar reports in literature. Children with developmental disorders performed poorer than typically developing peers on both Articulation Judgment and Articulation Correction Tests. These findings are supported by similar reports in the literature. While Sutherland and Gillon (2005) reported poor performance of preschool children with speech impairment on mispronunciation detection tasks, other investigators (Claesson &

Leitao, 2012; Marshall et al., 2010; Stackhouse et al., 2007) reported similar observations in children with SLI.

There was no difference observed between children at risk for dyslexia and typically developing children for any of the RAN tests. While children with SLI differed from typically developing children for all the RAN tests, those with SSD differed from typically developing peers only for the RAN Verbs test. Many studies have reported impaired RAN abilities in children with reading disability and children at risk for dyslexia (Araujo et al., 2011; Kirby et al., 2003; Pauly et al., 2011; Vaessen et al., 2010; Wolf et al., 2000; 2002), children with SLI (Lahey & Edwards, 1996; Miloshevic & Wukovic, 2017; Wiig et al., 1982) and also children with CAS (Zaretsky et al., 2010).

Overall, the clinical groups were heterogenous and the number of participants in each clinical group was small and unequal. Further, the distribution of participants of each clinical group in the four age ranges considered in the study varied widely. While children at risk for dyslexia were present only in the two older age groups (>4;0 - ≤4;6 and >4;6 - ≤5;0 years), there were no children with CAS in the age group of >4;6 - ≤5;0 years. Hence, results of group comparisons should be interpreted with caution and cannot be generalized. In general, it was seen that children with developmental disorders show deficits in phonological representations in comparison with typically developing children (as seen in the performance profiles of clinical groups – Figures 19 to 22). It is also observed that the performance patterns of children with different developmental disorders (SSD, SLI, at risk for dyslexia, CAS) are similar to that of typically developing children although a delay is evident. Further, there were similarities among children with different developmental disorders (SSD, SLI, at risk for dyslexia, CAS) with respect to the deficits seen in phonological representations. While the performance patterns were similar for RAN tests and Sentence Imitation test, a slightly different pattern was observed in their performance for Articulation Judgment and Articulation Correction tests in all the clinical groups. This indicates that the delay is more pronounced for Articulation Judgment and Articulation Correction tests compared to RAN and Sentence Imitation tests.

Further, observation of individual profiles of children with developmental disorders (Figures 23 to 31) revealed that performance of most children in the clinical groups was below the range established for typically developing children with a few exceptions. Performance on par with or better than the range for typically developing children was observed in few participants diagnosed as SSD or at risk for dyslexia. Further, this was particularly observed only for RAN tests and Sentence Imitation Test but not in the Articulation Judgment and Articulation Correction Tests for Vowels and Consonants. Although the participants in each of the clinical groups were matched for expressive language age with the typically developing group of participants, there was wide heterogeneity within the groups. The language profiles of individual participants within a clinical group were also found to be different and it may be plausible that there are subgroups within these clinical groups. However, detailed investigation of these aspects were beyond the scope of the current study and further research on assessment of phonological representations in large groups of children with developmental disorders can be carried out to verify these preliminary findings.

Nonetheless, it may be stated that the performance of children with developmental disorders on the test battery for phonological representations are poorer compared to typically developing children matched for expressive language abilities. *Thus, hypothesis 4 of the study stating there is no difference between typically developing children in the age range of 3-5 years and children with developmental disorders matched for expressive language abilities in performance on the test battery for phonological representations is rejected.*

In light of these findings and the evidences from literature reporting of poor phonological representations or access to/retrieval of the same in children with various developmental disorders, it may be presumed that deficits in phonological representations span across a variety of disorders such as SLI, SSD, at risk for dyslexia and CAS. Given the important role of phonological representations in various aspects of speech perception, speech production and also literacy skills, detailed assessment of phonological representations in these groups of children with developmental disorders may be warranted. In addition, training on developing and strengthening phonological representations are reported to be beneficial in developing literacy skills. Thus, inclusion of dimensions of phonological representations in the assessment and management protocols of children with developmental disorders can result in a holistic approach in the rehabilitation of such children.

SUMMARY AND CONCLUSIONS

Phonological processing abilities are crucial for the development of good oral and written language. One of the key components of phonological processing is phonological representations, which is considered as the repository for information about speech sounds in the long term memory. The development of phonological representations is extensively documented, particularly in infants and toddlers. While some of the investigators (Liberman et al., 1989; Morais et al., 1986) endorse the accessibility view stating that phonological representations are fully developed from birth, others (Fowler, 1991; Metsala & Walley, 1998; Walley, 1993) support the emergent view which proposes that the holistic representations present initially are gradually restructured with the growth in vocabulary of a child. Deficits in phonological representations are reported in children with a variety of developmental disorders, thereby impacting their speech, language and early literacy skills. Studies reported in the literature have emphasized the importance of examining phonological representations across languages to understand both the language specific and the universal factors that contribute to phonological representation skills (Anthony & Francis, 2005; Durgunoglu & Oney, 1999).

A large number of receptive and expressive tasks for the assessment of phonological representations in both typically developing children and children with developmental disorders are reported in the literature. Investigators have shown that the quality of phonological representations can be best assessed using tasks like speech gating, lexical judgment, sentence imitation, rapid naming and nonword repetition among others. The data with respect to phonological representation is abundant on young infants but is limited in pre-school children. The preschool years are crucial because the phonological awareness and literacy development in these years are heavily dependent on the processing of phonological representations (Elbro et al., 1998; McCardle et al., 2001; Vihman & Croft, 2007).

Native Kannada speakers who are admitted to schools with English as the medium of instruction are most often exposed to English for the first time in the school environment. The differences in the phonological properties of English and Kannada (a Dravidian language of South India) necessitate investigation of the underlying phonological representations of this population during the developmental period. Assessment of phonological representations in children with developmental disorders will facilitate a holistic approach in intervention. Further, availability of a common tool to assess children with different developmental disorders will make it possible to compare the development of phonological representations across these disorders.

The study aimed to develop and standardize a test battery for the assessment of phonological representations in typically developing native speakers of Kannada in the age range of 3-5 years. Further, the test battery was administered on few groups of children with developmental disorders such as Speech Sound Disorder (SSD), Specific Language Impairment (SLI), Childhood Apraxia of Speech (CAS) and children at risk for Dyslexia to test the utility of the battery in assessing phonological representations in clinical population.

The specific objectives of the study were [1] to investigate the effects of (a) gender (b) age and (c) stimuli on the performance in (i) Articulation Judgment Test (ii)

Articulation Correction Test (iii) Sentence Imitation Test and (iv) Rapid Automatized Naming (Nouns, Verbs and Size) Test in typically developing native speakers of Kannada in the age range of 3-5 years and [2] to compare the performance of children with developmental disorders (Children with Speech Sound Disorder, Specific Language Impairment, Childhood Apraxia of Speech and at risk for Dyslexia) with that of the typically developing children in various subsections of the test battery.

The study hypothesized that there is no significant effect of (a) gender (b) age and (c) stimuli on tasks tapping phonological representations in the test battery, viz., the Articulation Judgment Test, Articulation Correction Test, Sentence Imitation Test and Rapid Automatized Naming Test (Nouns, Verbs and Size) in Kannada speaking typical children between 3-5 years of age. It was also hypothesized that there is no significant difference between Kannada speaking typically developing children in the age range of 3-5 years and children with developmental disorders [Children with Speech Sound Disorder (SSD), Specific Language Impairment (SLI), Childhood Apraxia of Speech (CAS) and Children at risk for Dyslexia] matched for expressive language abilities in performance on the test battery for phonological representations.

Two groups of participants were included in the study, typically developing group and clinical group. The typically developing group included 240 typically developing native speakers of Kannada in the age range of 3-5 years residing in the city of Mysuru, Karnataka. They were further divided into four age groups (>3;0 - ≤3;6; >3;6 - ≤4;0; >4;0 - ≤4;6 and >4;6 - ≤5;0 years) with 60 participants in each group (30 Boys & 30 Girls). The clinical group consisted of a total of 30 children with developmental disorders (Speech Sound Disorder, Specific Language Impairment, Childhood

Apraxia of Speech and at risk for Dyslexia) with an expressive language age in the range of 3-5 years. Ethical clearance was obtained for the study and an informed consent was obtained from the parents/caregivers of all participants of the study.

Initially, a test battery for the assessment of phonological representations in typically developing native speakers of Kannada in the age range of 3-5 years was developed by the investigator following a thorough review of literature. Tasks reported to be effective in the assessment of various dimensions of phonological representation in children were selected and appropriate stimuli were developed in Kannada. The test battery was subjected to pilot study by administering it on 24 typically developing children in the age range of 3-5 years with six children each in age interval of six months (>3;0 - ≤3;6; >3;6 - ≤4;0; >4;0 - ≤4;6 and >4;6 - ≤5;0 years), in order to check for the appropriateness of the material developed, instructions given, response recording and scoring procedures. Based on the results of the pilot study, suitable modifications were incorporated and the test battery for phonological representations for Kannada speaking children was finalized.

The test battery was then administered on participants in the typically developing group and clinical group. The responses of the participants on various subsections of the test battery were analyzed and scored appropriately. Inter- and intra- judge reliability measures for the administration of the test battery were established and found to be good. Suitable statistical analyses were carried out using Statistical Package for the Social Sciences (Version 21) (SPSS Inc, Chicago).

The salient findings of the study were as follows:

1. There was no effect of gender on the performance of typically developing native speakers of Kannada in the age range of 3-5 years on tasks assessing phonological representations i.e. Articulation Judgment, Articulation Correction, Sentence Imitation and Rapid Automatized Naming. Thus the first hypothesis of the study was accepted.
2. There was a significant effect of age on the performance of typically developing native speakers of Kannada in the age range of 3-5 years on tasks such as Articulation Judgment, Articulation Correction, Sentence Imitation and Rapid Automatized Naming, thereby revealing developmental trends in phonological representations during preschool years. Hence, the second hypothesis of the study was rejected.
3. There was a significant effect of stimuli on the performance of typically developing native speakers of Kannada in the age range of 3-5 years on tasks such as Articulation Judgment, Articulation Correction, Sentence Imitation and Rapid Automatized Naming, thereby rejecting the third hypothesis.
4. Children in the clinical group performed poorer than the typically developing children matched for expressive language abilities on various sections of the test battery. Thus the fourth hypothesis of the study was rejected.

Analyses of the results were carried out in order to investigate the effects of gender, age and stimuli on the performance of typically developing participants in various subsections of the test battery. The performance of the participants in the clinical group was also compared with that of the typically developing group. Some of the salient findings in typical and clinical group were as follows:

Typical group of participants

1. There was no significant effect of gender on the performance in any of the tasks of the test battery.
2. Articulation Judgment and Articulation Correction tests were suitable for typically developing children beyond the age of 3;6 years.
3. There was a significant effect of the stimuli used in the Articulation Judgment Test, in addition to a significant effect of age. Typically developing participants in each of the age groups performed better for consonants than that of vowels in Articulation Judgment tests.
4. A developmental trend was also observed in the percentage of error patterns in the Articulation Judgment Test for vowels and consonants. Percentage of error patterns were distinct for participants in the age group of >3;6 - ≤4;0 years whereas, overlap in some of the error patterns was observed between those in the age group of >4;0 - ≤4;6 years and >4;6 - ≤5;0 years. Vowel errors decreased as the tongue height of substituted vowels increased from low/mid to high or when the substituted vowel moved from front to back in terms of tongue advancement. On the other hand, with respect to place of articulation, errors were maximum when palatal sounds were substituted for dental sounds and with respect to manner of articulation, errors were maximum when stops were substituted for flap. In terms of voicing, substitution of unvoiced for voiced consonants resulted in higher error percentages than the substitution of voiced for unvoiced consonants in all the age groups.
5. A developmental trend was observed in the Articulation Correction Tests for both judgment and production of target vowels and consonants. Although the effect of stimulus was not significant, scores obtained for correct production of

target vowels were greater than that of consonants in the lower age group while no such differences were observed in the higher age groups.

6. The total number of words and syllables produced by the typically developing participants increased with increase in age in the Sentence Imitation Test, thereby confirming the developmental trend. All word shapes, except bisyllables were significantly different in each of the age groups, while CV and CVC were found to be significantly different among the syllable shapes. Similar results were observed on comparing the percentage of each type of word and syllable shape in the imitated utterances of the participants with the corresponding target values in the sentence stimuli. Specifically, the percentage of bisyllables produced by the participants was greater than the target values and this finding was more prominent in the lower age groups.
7. A significant effect of both age and stimuli was observed in the performance of typically developing participants on the RAN tests, revealing a developmental trend in speed naming abilities. The differences in performances were evident mainly across participants with an interage interval of one year rather than six months, particularly for RAN Verbs. In each of the age groups, participants performed RAN Size task the fastest, followed by RAN Nouns and RAN Verbs.

Clinical group

1. Comparison of the composite scores of clinical group with that of the typically developing group showed poor performance of participants in the clinical group in all subsections of the test battery.

2. Analyses of the responses of participants in each of the clinical groups (SSD, SLI, at risk for dyslexia) on various sections of the test battery revealed poor performance in comparison with typically developing children matched for expressive language abilities. Comparisons across the various clinical groups showed that children at risk for dyslexia performed better on most tasks followed by children with SSD and SLI.
3. Comparison of group performance profiles of children with different developmental disorders (SSD, SLI, CAS, at risk for dyslexia) with the typically developing group showed similar patterns for RAN tests and Sentence Imitation test, and a slightly different pattern for Articulation Judgment and Articulation Correction tests. In other words, the performance of participants in the clinical groups was much poorer than their typically developing peers for Articulation Judgment and Articulation Correction tests compared to RAN and Sentence Imitation. However, similar performance profiles were observed among children with different developmental disorders (SSD, SLI, CAS, at risk for dyslexia) on the test battery for phonological representations.
4. Although group differences were present, few individual participants diagnosed as SSD or at risk for dyslexia performed RAN tasks and Sentence Imitation Tests on par with or better than the matched typically developing children. However, such exceptions were not observed in the Articulation Judgment and Articulation Correction Tests for Vowels and Consonants. Considering the wide heterogeneity within the clinical groups and the small sample size, these observations cannot be generalized and further research on assessment of phonological representations in large groups of children with

developmental disorders needs to be carried out to verify these preliminary findings.

Limitations of the Study

1. The stimuli used in the Articulation Judgment Test for Vowels and Consonants involved substitution patterns in the target words to prepare the nonword lists. However, all combinations of substitution patterns of vowels and consonants were not included and also the number of occurrence of each of the patterns was not uniform. Thus, although an attempt was made to study the effect of individual substitution patterns, detailed statistical analyses could not be carried out.
2. Consonant substitution patterns in the stimuli used in the Articulation Judgment Test for Consonants involved variations from a minimum of one to a maximum of three distinctive features. However, the error responses were analyzed in terms of place, manner and voicing but the differences in the number of features were not taken into account.
3. The small sample size in the clinical group and the unequal distribution of participants in each of the clinical groups limits generalization of the results in this group of participants.

Future recommendations

1. Further research to develop more number of tasks to measure each dimension of phonological representations in order to obtain more evidences about developmental aspects of the same is required.

2. Systematic manipulation of the target words in the Articulation Judgment Tests including all possible substitution patterns for vowels and consonants in adequate numbers to study the effect of individual substitution patterns is required. Further, the effect of the number of features manipulated and also variations in the syllable shape of the target words can be studied.
3. The stimulus presentation and response recording formats/platforms can be computerized using suitable software programs in order to improve the face validity of the test battery and also to facilitate measurement of response parameters like reaction time.
4. Inclusion of more number of participants in each clinical group across different age groups will give better insight about the nature of phonological representations in these populations.
5. Children with other developmental disorders like Stuttering, Autism Spectrum Disorders, Hearing Impairment etc can be assessed for phonological representations.

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APPENDIX 1

Vowels and Consonants in Kannada Language

I. Vowels in Kannada

ಅ	ಆ	ಇ	ಈ	ಉ	ಊ	ಎ	ಏ	ಒ	ಓ
a	a:	I	i	ʊ	u	e	e:	o	o:

II. Classification of Vowels in Kannada based on Tongue Height and Tongue Advancement (As given in Sreedevi, 2000)

Tongue Height	Tongue Advancement		
	Front	Central	Back
High	I, i	-	ʊ, u
Mid	e, e:	-	o, o:
Low	-	a, a:	-

III. Consonants in Kannada

ಕ	ಖ	ಗ	ಘ	ಙ	ಚ	ಛ	ಜ	ಝ	ಞ
k	k^h	g	g^h	ṅ	ʧ	$ʧ^h$	ʤ	$ʤ^h$	ñ
ಟ	ಠ	ಡ	ಢ	ಣ	ತ	ಥ	ದ	ಧ	ನ
ṭ	$ṭ^h$	ḍ	$ḍ^h$	ṇ	t̪	$t̪^h$	d̪	$d̪^h$	n
ಪ	ಫ	ಬ	ಭ	ಮ	ಯ	ರ	ಲ	ವ	ಶ
p	p^h	b	b^h	m	j	r	l	v	ʃ
ಷ	ಸ	ಹ	ಳ						
ṣ	s	h	ḷ						

IV. Classification of Consonants in Kannada based on Place of Articulation, Manner of Articulation and Voicing (Upadhyaya, 1972)

	Bilabial	Labiodental	Dental	Alveolar	Palatal	Retroflex	Velar	Glottal
Stops	p, b	f, v	t, d			ʈ, ɖ	k, g	
Fricatives				s	ʃ	ʂ		h
Affricates					ʧ, ʤ			
Nasals	m		n		ñ	ɳ	ṅ	
Continuant	w				j			
Lateral				l		ɭ		
Flap				r				
Stops								

Note: Symbols to the left in a cell represent unvoiced consonants and those to the right indicate voiced consonants.

APPENDIX 2

Test Battery for Phonological Representations in Kannada Speaking Children

GENERAL INSTRUCTIONS

1) The test should be administered on native speakers of Kannada language studying in preschools with English as the medium of instruction.
2) The expressive language age of the child should be in the range of 3-5 years.
3) Testing should be carried out in a quiet environment with adequate light and good ventilation to avoid any distractions.
4) The child should first be instructed regarding the subsections of the test.
5) Practice trials should be given for each subsection to familiarize the child with the task and demonstrate how to respond before presenting the test stimuli.
6) Picture stimuli as given in this test battery only should be used to present the stimulus.
7) The responses of the child should be recorded in the Response Sheet given in Appendix 7.

INSTRUCTIONS FOR TEST ADMINISTRATION AND SCORING PATTERN

I. Receptive Picture Vocabulary Test

1) About the test

This test is only used as a control task to ensure familiarity of the stimuli used in other sections of the test battery. It consists of 33 words which are represented as pictures and presented to the child for a picture identification task. Each target word stimuli is presented along with two semantically related distracters in word form. The stimuli for Receptive Picture Vocabulary Test are given in Appendix 3.

2) Instructions

The child should be shown one picture plate at a time and instructed to point to the picture named by the examiner.

3) Scoring

A correct response by the child should be offered a score of ‘1’ and an incorrect response or no response by the child should be offered a score of ‘0’. The maximum score that can be obtained by a child is 33. It may however be noted that the scores in this section are considered only to facilitate administration of other sections of the test battery in which these words are repeatedly used as stimuli. If the child obtains a score of ‘0’, the child should be familiarized with the given item/s by the examiner before administering the test battery. Practice sessions should be held for each child, where the examiner has to name of the items depicted in the picture and then present the same for picture identification task (modelling) until the child can correctly identify the target picture.

4) Stimuli for Receptive Picture Vocabulary Test

Stimuli for Practice Trials

Sl.No	Stimuli		
	Target (In Kannada)	IPA	Meaning (In English)
1.	ಬಾಳೆಹಣ್ಣು	/baḷehəṇṇu/	Banana
2.	ಈರುಳ್ಳಿ	/iruḷḷi/	Onion

Test Stimuli

Sl. No.	Stimuli			Sl. No.	Stimuli		
	Target (In Kannada)	IPA	Meaning (In English)		Target (In Kannada)	IPA	Meaning (In English)
1.	ಸ್ನಾನ	/snāna/	Bath	20.	ಟ್ರೇನು	/ṭrēnƱ/	Train
2.	ಛತ್ರಿ	/tʃ^{h}ət̪rI/	Umbrella	21.	ಬ್ಲೇಡು	/blēḍƱ/	Blade
3.	ನಿದ್ರೆ	/nId̪re/	Sleep	22.	ಸ್ಕೂಲು	/skūlƱ/	School
4.	ಇಡ್ಲಿ	/IḍlI/	Idli	23.	ಬ್ರಷು	/brəʃƱ/	Brush
5.	ರಕ್ತ	/rəkt̪a/	Blood	24.	ಶರ್ಟು	/ʃərṭƱ/	Shirt
6.	ಚಕ್ರ	/tʃəkra/	Wheel	25.	ಸ್ಲೇಟು	/slēṭƱ/	Slate
7.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/	Grapes	26.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/	Icecream
8.	ರಸ್ತೆ	/rəst̪e/	Road	27.	ಕ್ಯಾಮರ	/kæməra/	Camera
9.	ಚಿತ್ರ	/tʃIt̪ra/	Picture	28.	ಪೆನ್ಸಿಲ್	/pensIl/	Pencil
10.	ಚಂದ್ರ	/tʃənd̪ra/	Moon	29.	ಸೈಕಲ್	/saIkəl/	Cycle
11.	ಸೂರ್ಯ	/sūrja/	Sun	30.	ಡಾಕ್ಟರ್	/dɔkṭər/	Doctor
12.	ರಾತ್ರಿ	/rāt̪ri/	Night	31.	ಸ್ಕೂಟರ್	/skūṭər/	Scooter
13.	ಪಕ್ಷಿ	/pəkʃi/	Bird	32.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/	Biscuit
14.	ಕುರ್ಚಿ	/kƱrtʃi/	Chair	33.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/	Postbox
15.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/	Hospital				
16.	ಸಮುದ್ರ	/səmƱd̪ra/	Sea				
17.	ಪುಸ್ತಕ	/pƱst̪əka/	Book				
18.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/	Star				
19.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/	Autorick-shaw				

II. Articulation Judgment Test for: a) Vowels and b) Consonants

1) About the test

This test involves presentation of pictures along with audio recorded word stimuli. The audio recorded stimuli should be presented to the participants through headphones from a computer/laptop in which it is stored. The corresponding picture stimuli should be presented using the target pictures given in Appendix 4. Three trials each are given for vowels and consonants respectively using the six randomized stimuli lists. The same set of target pictures are presented in each trial in the order of the audio recorded stimuli lists. This test includes two subtests as follows:

c) Articulation Judgment Test for Vowels: This test consists of 66 word stimuli including 33 true words with no vowel change and 33 nonwords with one vowel substituted in the true word in each trial. There are three trials overall and for each trial the order of the stimuli in the word list is different as shown in the following pages.

d) Articulation Judgment Test for Consonants: This test consists of 66 word stimuli including 33 true words with correct consonant forms and 33 nonwords with one consonant substituted in the true word in each trial. There are three trials overall and for each trial the order of the stimuli in the word list is different as shown in the following pages.

2) Instructions

The child should be instructed to listen to the word presented through the headphones while he/she is encouraged to simultaneously look at the corresponding picture showed by the examiner. He/She should be instructed to judge if the name of the object heard through the headphones depicted the picture placed in front of him/her correctly or not. The child should be instructed to respond by saying “Yes/No” or “Correct/Incorrect (Wrong)”.

3) Scoring

Quantitative analysis: Every correct response given by the child should be given a score of ‘1’ and incorrect response/no response should be given a score of ‘0’. The maximum score in each trial of this test is 66.

Qualitative analysis: This should be carried out by the examiner only for the stimuli that are judged by the child as correct when the expected response is incorrect. The errors should be noted by the examiner for tongue height and tongue advancement for vowels as follows:

Check for the pattern of substitution in the stimuli in which the child failed to judge the mispronunciation. Refer to Appendix 5A for error analysis key for vowels. For example, consider the target word 'ದ್ರಾಕ್ಷಿ' /d̪rākʃi/ presented as 'ದ್ರಾಕ್ಷ' /d̪rākʃa/. The child is expected to respond to this stimulus as "Incorrect/Wrong". Instead, if the child responds as "Correct", this will be considered for qualitative analysis. The error pattern in this stimulus is the low, central vowel /a/ being substituted for high, front vowel /I/. Hence, with respect to tongue height, this is considered as one instance of substitution of low vowel for high vowel and with respect to tongue advancement, it is a case of substitution of central vowel for front vowel. Similarly, the total number of errors in stimuli judged incorrectly by the child in the three trials should be computed for each of the substitution pattern and tabulated in the tables given in the response sheet (Appendix 7). The percentage of each error pattern is computed by dividing the number of particular error pattern by the total number of opportunities available for the respective error pattern.

The errors in consonants should be noted by the examiner for (a) place of articulation, (b) manner of articulation and (c) voicing as follows:

Check for the pattern of substitution in the stimuli in which the child failed to judge the mispronunciation. Refer to Appendix 5B for error analysis key for consonants. For example, consider the target word 'ಡಾಕ್ಟರ್' /dɔkṭər/ presented as 'ಡಾಲ್ಟರ್' /dɔlṭər/. The child is expected to respond to this stimulus as "Incorrect/Wrong". Instead, if the child responds as "Correct", this will be considered for qualitative analysis. The error pattern in this stimulus is the voiced-alveolar-lateral consonant /l/ being substituted for unvoiced-velar-stop consonant /k/. Hence, this is considered as one instance of substitution of alveolar for velar with respect to place of articulation; one instance of substitution of lateral for stop in terms of manner of articulation and as one instance of substitution of voiced for unvoiced in terms of voicing. Similarly, the total number of errors in stimuli judged incorrectly by the child should be computed separately for substitution patterns of place, manner and voicing aspects in the three trials and tabulated in the respective tables in the response sheet (Appendix 7). The percentage of each error pattern is computed by dividing the number of particular error pattern by the total number of opportunities available for the respective error pattern.

Stimuli for Articulation Judgment Test for Vowels and Consonants

Sl. No.	Target Stimuli		Stimuli for Articulation Judgment for Vowels		Stimuli for Articulation Judgment for Consonants	
	Target (In Kannada)	IPA	Target (In Kannada)	IPA	Target (In Kannada)	IPA
1.	ಸ್ನಾನ	/snāna/	ಸ್ನೀನ	/snīna/	ಗ್ನಾನ	/gnāna/
2.	ಛತ್ರಿ	/tʃʰət̪rI/	ಛತ್ರೆ	/tʃʰət̪re/	ಛಕ್ರಿ	/tʃʰəkrI/
3.	ನಿದ್ರೆ	/nId̪re/	ನದ್ರೆ	/nəd̪re/	ನಿತ್ರೆ	/nIt̪re/
4.	ಇಡ್ಲಿ	/IḍlI/	ಇಡ್ಲು	/IḍlƱ/	ಇಟ್ಲಿ	/IṭlI/
5.	ರಕ್ತ	/rəkt̪a/	ರುಕ್ತ	/rƱkt̪a/	ರತ್ತ	/rət̪t̪a/
6.	ಚಕ್ರ	/tʃəkra/	ಚಕ್ರಿ	/tʃəkri/	ಚತ್ರ	/tʃət̪ra/
7.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/	ದ್ರಾಕ್ಷ	/d̪rākʃa/	ಪ್ರಾಕ್ಷಿ	/prākʃi/
8.	ರಸ್ತೆ	/rəst̪e/	ರಸ್ತೊ	/rəst̪o/	ಹಸ್ತೆ	/həst̪e/
9.	ಚಿತ್ರ	/tʃIt̪ra/	ಚಿತ್ರಿ	/tʃIt̪ri/	ಚಿಕ್ರ	/tʃIkra/
10.	ಚಂದ್ರ	/tʃənd̪ra/	ಚಂದ್ರೆ	/tʃənd̪re/	ಚಂಗ್ರ	/tʃəngra/
11.	ಸೂರ್ಯ	/sūrja/	ಸಾರ್ಯ	/sārja/	ಸೂರ್ಲ	/sūrla/
12.	ರಾತ್ರಿ	/rāt̪ri/	ರೂತ್ರಿ	/rūt̪ri/	ಬಾತ್ರಿ	/bāt̪ri/
13.	ಪಕ್ಷಿ	/pəkʃi/	ಪಕ್ಷೆ	/pəkʃe/	ಜಕ್ಷಿ	/ʤəkʃi/
14.	ಕುರ್ಚಿ	/kƱrtʃi/	ಕುರ್ಚು	/kƱrtʃʊ/	ಚುರ್ಚಿ	/tʃƱrtʃi/
15.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/	ಆಸ್ಪಿತ್ರೆ	/a:spIt̪re/	ಆಸ್ಕತ್ರೆ	/a:skət̪re/
16.	ಸಮುದ್ರ	/səmƱd̪ra/	ಸಮಿದ್ರ	/səmId̪ra/	ಸನುದ್ರ	/sənƱd̪ra/
17.	ಪುಸ್ತಕ	/pƱst̪əka/	ಪಸ್ತಕ	/pəst̪əka/	ಪುಕ್ತಕ	/pƱkt̪əka/
18.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/	ನಕ್ಷುತ್ರ	/nəkʃƱt̪ra/	ನಕ್ಷಜ್ರ	/nəkʃəʤra/
19.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/	ಆಟೀರಿಕ್ಷಾ	/āṭirIkʃa/	ಆಗೋರಿಕ್ಷಾ	/āgōrIkʃa/
20.	ಟ್ರೇನು	/ṭrēnƱ/	ಟ್ರೀನು	/ṭrinƱ/	ಪ್ರೇನು	/prēnƱ/
21.	ಬ್ಲೇಡು	/blēḍƱ/	ಬ್ಲೂಡು	/blūḍƱ/	ಕ್ಲೇಡು	/klēḍƱ/
22.	ಸ್ಕೂಲು	/skūlƱ/	ಸ್ಕೀಲು	/skīlƱ/	ಸ್ಕೂವು	/skūwƱ/
23.	ಬ್ರಷು	/brəʃƱ/	ಬ್ರಿಷು	/brIʃƱ/	ದ್ರಷು	/d̪rəʃƱ/
24.	ಶರ್ಟು	/ʃərṭƱ/	ಶರ್ಟ	/ʃərṭa/	ತರ್ಟು	/t̪ərṭƱ/
25.	ಸ್ಲೇಟು	/slēṭƱ/	ಸ್ಲೋಟು	/slōṭƱ/	ಪ್ಲೇಟು	/plēṭƱ/
26.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/	ಐಸ್‌ಕ್ರೂಂ	/aIskrūm/	ಐಸ್‌ತ್ರೀಂ	/aIst̪rīm/
27.	ಕ್ಯಾಮರ	/kæməra/	ಕ್ಯಾಮೆರ	/kæmera /	ಸ್ಯಾಮರ	/sæməra/
28.	ಪೆನ್ಸಿಲ್	/pensIl/	ಪೆನ್ಸಲ್	/pensəl/	ಕೆನ್ಸಿಲ್	/kensIl/
29.	ಸೈಕಲ್	/saIkəl/	ಸೈಕುಲ್	/saIkƱl/	ಪೈಕಲ್	/paIkəl/
30.	ಡಾಕ್ಟರ್	/dɔkṭər/	ಡಾಕ್ಟೆರ್	/dɔkṭer/	ಡಾಲ್ಟರ್	/dɔlṭər/
31.	ಸ್ಕೂಟರ್	/skūṭər/	ಸ್ಕೂಟುರ್	/skūṭƱr/	ಸ್ಪೂಟರ್	/spūṭər/
32.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/	ಬಿಸ್ಕುಟ್	/bIskƱṭ/	ಬಿತ್ಕೆಟ್	/bIt̪keṭ/
33.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/	ಪೋಸ್ಟ್‌ಬೀಕ್ಸ್	/posṭbiks/	ಪೋಸ್ಟ್‌ಮಾಕ್ಸ್	/pōsṭmɔks/

Stimuli for Articulation Judgment Test for Vowels – Trial 1

Practice Trials

Sl. N0.	Stimuli: Target (In Kannada)	Stimuli: IPA
1.	ಕಾರು	/kārƱ/
2.	ಗಾಳಿಪಟ	/gāḷIpƱṭa/

Test Stimuli

Sl. No.	Stimuli: In Kannada	Stimuli: IPA	Sl. No.	Stimuli: In Kannada	Stimuli: IPA
1.	ಸ್ಕೂಲು	/skūlƱ/	34.	ಸ್ಕೂಟರ್	/skūṭər/
2.	ರುಕ್ತ	/rƱkt̪a/	35.	ಬ್ಲೂಡು	/blūḍƱ/
3.	ಚಕ್ರ	/tʃəkra/	36.	ಸ್ಲೋಟು	/slōṭƱ/
4.	ಸ್ನಾನ	/snāna/	37.	ನಕ್ಷುತ್ರ	/nəkʃƱt̪ra/
5.	ಪುಸ್ತಕ	/pƱst̪əka/	38.	ಕುರ್ಚು	/kƱrtʃʊ/
6.	ಚಕ್ರಿ	/tʃəkri/	39.	ಚಂದ್ರೆ	/tʃənd̪re/
7.	ಐಸ್‌ಕ್ರೂಂ	/aIskrūm/	40.	ಸೈಕುಲ್	/saIkƱl/
8.	ಬಿಸ್ಕುಟ್	/bIskƱṭ/	41.	ಬ್ಲೇಡು	/blēḍƱ/
9.	ಡಾಕ್ಟರ್	/dɔkṭər/	42.	ಸಾರ್ಯ	/sārja/
10.	ಇಡ್ಲು	/IḍlƱ/	43.	ದ್ರಾಕ್ಷ	/d̪rākʃa/
11.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/	44.	ಪಕ್ಷೆ	/pəkʃe/
12.	ಸ್ನೀನ	/snīna/	45.	ಕ್ಯಾಮರ	/kæməra/
13.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/	46.	ಛತ್ರೆ	/tʃʰət̪re/
14.	ರಕ್ತ	/rəkt̪a/	47.	ರಸ್ತೆ	/rəst̪e/
15.	ಪಸ್ತಕ	/pəst̪əka/	48.	ಪೋಸ್ಟ್‌ಬೀಕ್ಸ್	/pōsṭbiks/
16.	ಟ್ರೇನು	/ṭrēnƱ/	49.	ರೂತ್ರಿ	/rūt̪ri/
17.	ಇಡ್ಲಿ	/IḍlI/	50.	ಪೆನ್ಸಿಲ್	/pensIl/
18.	ಕ್ಯಾಮೆರ	/kæmera /	51.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/
19.	ಪೆನ್ಸಲ್	/pensəl/	52.	ಬ್ರಿಷು	/brIʃƱ/
20.	ಆಟೀರಿಕ್ಷಾ	/āṭirIkʃa/	53.	ಬ್ರಷು	/brəʃƱ/
21.	ಚಂದ್ರ	/tʃənd̪ra/	54.	ಚಿತ್ರಿ	/tʃIt̪ri/
22.	ಸ್ಕೀಲು	/skīlƱ/	55.	ಸೂರ್ಯ	/sūrja/
23.	ಡಾಕ್ಟೆರ್	/dɔkṭer/	56.	ಶರ್ಟು	/ʃərṭƱ/
24.	ರಾತ್ರಿ	/rāt̪ri/	57.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/
25.	ಸಮಿದ್ರ	/səmId̪ra/	58.	ಟ್ರೀನು	/ṭrinƱ/
26.	ಛತ್ರಿ	/tʃʰət̪rI/	59.	ಸ್ಲೇಟು	/slēṭƱ/
27.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/	60.	ಚಿತ್ರ	/tʃIt̪ra/
28.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/	61.	ರಸ್ತೊ	/rəst̪o/
29.	ಸ್ಕೂಟುರ್	/skūṭƱr/	62.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/
30.	ಆಸ್ಪಿತ್ರೆ	/a:spIt̪re/	63.	ಸಮುದ್ರ	/səmƱd̪ra/
31.	ಕುರ್ಚಿ	/kƱrtʃi/	64.	ನಿದ್ರೆ	/nId̪re/
32.	ನದ್ರೆ	/nəd̪re/	65.	ಪಕ್ಷಿ	/pəkʃi/
33.	ಶರ್ಟ	/ʃərṭa/	66.	ಸೈಕಲ್	/saIkəl/

Stimuli for Articulation Judgment Test for Vowels – Trial 2

Practice Trials

Sl. No.	Stimuli	
	Target (In Kannada)	IPA
1.	ನೂಯಿ	/nūji/
2.	ಚಾಕು	/t̪ʃāku/

Test Stimuli

Sl.No.	Stimuli		Sl.No.	Stimuli	
	In Kannada	IPA		In Kannada	IPA
1.	ಸ್ಕೂಟುರ್	/skūṭƱr/	34.	ಛತ್ರೆ	/t̪ʃʰət̪re/
2.	ಚಕ್ರಿ	/t̪ʃəkri/	35.	ಚಂದ್ರ	/t̪ʃənd̪ra/
3.	ಸ್ಕೂಲು	/skūlƱ/	36.	ಪಸ್ತಕ	/pəst̪əka/
4.	ಸ್ಕೂಟರ್	/skūṭər/	37.	ಐಸ್‌ಕ್ರೂಂ	/aIskrūm/
5.	ಪುಸ್ತಕ	/pƱst̪əka/	38.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/
6.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/	39.	ಪಕ್ಷಿ	/pəkʃi/
7.	ಆಟೀರಿಕ್ಷಾ	/āṭirIkʃa/	40.	ಸ್ಲೋಟು	/slōṭƱ/
8.	ಕ್ಯಾಮರ	/kæməra/	41.	ಸೈಕುಲ್	/saIkƱl/
9.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/	42.	ರಸ್ತೊ	/rəst̪o/
10.	ಡಾಕ್ಟರ್	/dɔkṭər/	43.	ಚಿತ್ರ	/t̪ʃIt̪ra/
11.	ಸಮುದ್ರ	/səmƱd̪ra/	44.	ರಕ್ತ	/rəkt̪a/
12.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/	45.	ಟ್ರೀನು	/ṭrinƱ/
13.	ಬ್ಲೇಡು	/blēḍƱ/	46.	ಚಿತ್ರಿ	/t̪ʃIt̪ri/
14.	ಪಕ್ಷೆ	/pəkʃe/	47.	ಕ್ಯಾಮೆರ	/kæmera /
15.	ಪೋಸ್ಟ್‌ಬೀಕ್ಸ್	/pōsṭbiks/	48.	ನದ್ರೆ	/nəd̪re/
16.	ಬ್ರಿಷು	/brIʃƱ/	49.	ಸೈಕಲ್	/saIkəl/
17.	ಚಕ್ರ	/t̪ʃəkra/	50.	ಚಂದ್ರೆ	/t̪ʃənd̪re/
18.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/	51.	ದ್ರಾಕ್ಷ	/d̪rākʃa/
19.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/	52.	ರುಕ್ತ	/rƱkt̪a/
20.	ಕುರ್ಚು	/kƱrt̪ʃʊ/	53.	ಬಿಸ್ಕುಟ್	/bIskƱṭ/
21.	ಸ್ಕೀಲು	/skīlƱ/	54.	ಸ್ಲೇಟು	/slēṭƱ/
22.	ಶರ್ಟ	/ʃərṭa/	55.	ಬ್ರಷು	/brəʃƱ/
23.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/	56.	ಕುರ್ಚಿ	/kƱrt̪ʃi/
24.	ಛತ್ರಿ	/t̪ʃʰət̪rI/	57.	ಸ್ನಾನ	/snāna/
25.	ಶರ್ಟು	/ʃərṭƱ/	58.	ನಿದ್ರೆ	/nId̪re/
26.	ಇಡ್ಲಿ	/IḍlI/	59.	ನಕ್ಷುತ್ರ	/nəkʃƱt̪ra/
27.	ಇಡ್ಲು	/IḍlƱ/	60.	ಪೆನ್ಸಲ್	/pensəl/
28.	ಆಸ್ಪಿತ್ರೆ	/a:spIt̪re/	61.	ಬ್ಲೂಡು	/blūḍƱ/
29.	ರಸ್ತೆ	/rəst̪e/	62.	ಸ್ನೀನ	/snīna/
30.	ಸಾರ್ಯ	/sārja/	63.	ಟ್ರೇನು	/ṭrēnƱ/
31.	ಪೆನ್ಸಿಲ್	/pensIl/	64.	ಡಾಕ್ಟೆರ್	/dɔkṭer/
32.	ರೂತ್ರಿ	/rūt̪ri/	65.	ಸೂರ್ಯ	/sūrja/
33.	ರಾತ್ರಿ	/rāt̪ri/	66.	ಸಮಿದ್ರ	/səmId̪ra/

Stimuli for Articulation Judgment Test for Vowels – Trial 3

Practice Trials

S.N.	Stimuli	
	Target (In Kannada)	IPA
1.	ಆನೆ	/āne/
2.	ಕಿನ್ನಡಿ	/kInnəḍi/

Test Stimuli

Sl.No.	Stimuli		Sl.No.	Stimuli	
	In Kannada	IPA		In Kannada	IPA
1.	ಇಡ್ಲಿ	/IḍlI/	34.	ಬ್ಲೂಡು	/blūḍƱ/
2.	ಛತ್ರಿ	/tʃʰət̪rI/	35.	ಸಾರ್ಯ	/sārja/
3.	ಸ್ನಾನ	/snāna/	36.	ಚಕ್ರ	/tʃəkra/
4.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/	37.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/
5.	ಸ್ನೀನ	/snīna/	38.	ಬಿಸ್ಕುಟ್	/bIskƱṭ/
6.	ಸೂರ್ಯ	/sūrja/	39.	ಸ್ಲೋಟು	/slōṭƱ/
7.	ಆಟೀರಿಕ್ಷಾ	/āṭirIkʃa/	40.	ಚಂದ್ರೆ	/tʃənd̪re/
8.	ಚಂದ್ರ	/tʃənd̪ra/	41.	ಸಮುದ್ರ	/səmƱd̪ra/
9.	ಸ್ಕೂಲು	/skūlƱ/	42.	ರಕ್ತ	/rəkt̪a/
10.	ಟ್ರೀನು	/ṭrinƱ/	43.	ಬ್ರಷು	/brəʃƱ/
11.	ಆಸ್ಪಿತ್ರೆ	/a:spIt̪re/	44.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/
12.	ಕುರ್ಚು	/kƱrtʃʊ/	45.	ಸೈಕುಲ್	/saIkƱl/
13.	ಸ್ಕೂಟರ್	/skūṭər/	46.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/
14.	ಪೋಸ್ಟ್‌ಬೀಕ್ಸ್	/pōsṭbiks/	47.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/
15.	ಚಿತ್ರಿ	/tʃIt̪ri/	48.	ಡಾಕ್ಟರ್	/dɔkṭər/
16.	ಛತ್ರೆ	/tʃʰət̪re/	49.	ಕ್ಯಾಮರ	/kæməra/
17.	ಕುರ್ಚಿ	/kƱrtʃi/	50.	ಶರ್ಟ	/ʃərṭa/
18.	ಸ್ಲೇಟು	/slēṭƱ/	51.	ಚಿತ್ರ	/tʃIt̪ra/
19.	ಟ್ರೇನು	/ṭrēnƱ/	52.	ಪೆನ್ಸಿಲ್	/pensIl/
20.	ಇಡ್ಲು	/IḍlƱ/	53.	ರಾತ್ರಿ	/rāt̪ri/
21.	ಚಕ್ರಿ	/tʃəkri/	54.	ಪಕ್ಷೆ	/pəkʃe/
22.	ಡಾಕ್ಟೆರ್	/dɔkṭer/	55.	ಸ್ಕೀಲು	/skīlƱ/
23.	ಪೆನ್ಸಲ್	/pensəl/	56.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/
24.	ನಿದ್ರೆ	/nId̪re/	57.	ಪಸ್ತಕ	/pəst̪əka/
25.	ಬ್ರಿಷು	/brIʃƱ/	58.	ನದ್ರೆ	/nəd̪re/
26.	ದ್ರಾಕ್ಷ	/d̪rākʃa/	59.	ಶರ್ಟು	/ʃərṭƱ/
27.	ಪಕ್ಷಿ	/pəkʃi/	60.	ರಸ್ತೊ	/rəst̪o/
28.	ಸ್ಕೂಟುರ್	/skūṭƱr/	61.	ಬ್ಲೇಡು	/blēḍƱ/
29.	ಕ್ಯಾಮೆರ	/kæmera /	62.	ರೂತ್ರಿ	/rūt̪ri/
30.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/	63.	ಸಮಿದ್ರ	/səmId̪ra/
31.	ರಸ್ತೆ	/rəst̪e/	64.	ನಕ್ಷುತ್ರ	/nəkʃƱt̪ra/
32.	ಐಸ್‌ಕ್ರೂಂ	/aIskrūm/	65.	ಪುಸ್ತಕ	/pƱst̪əka/
33.	ಸೈಕಲ್	/saIkəl/	66.	ರುಕ್ತ	/rƱkt̪a/

Stimuli for Articulation Judgment Test for Consonants – Trial 1

Practice Trials

Sl.No.	Stimuli	
	Target (In Kannada)	IPA
1.	ತುದುರೆ	/t̪Ʊd̪Ʊre/
2.	ಟೋಪಿ	/ṭōpi/

Test Stimuli

Sl.No.	Stimuli		Sl.No.	Stimuli	
	In Kannada	IPA		In Kannada	IPA
1.	ಪುಕ್ತಕ	/pƱkt̪əka/	34.	ಟ್ರೇನು	/ṭrēnƱ/
2.	ಸೂರ್ಲ	/sūrla/	35.	ಸ್ಕೂಲು	/skūlƱ/
3.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/	36.	ಪ್ಲೇಟು	/plēṭƱ/
4.	ಇಟ್ಲಿ	/IṭlI/	37.	ಸಮುದ್ರ	/səmƱd̪ra/
5.	ನಿತ್ರೆ	/nIt̪re/	38.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/
6.	ಸೈಕಲ್	/saIkəl/	39.	ಸ್ಯಾಮರ	/sæməra/
7.	ಹಸ್ತೆ	/həst̪e/	40.	ಕ್ಯಾಮರ	/kæməra/
8.	ಚಿತ್ರ	/tʃIt̪ra/	41.	ರಕ್ತ	/rəkt̪a/
9.	ಚಂದ್ರ	/tʃənd̪ra/	42.	ಛಕ್ರಿ	/tʃ^{h}əkrI/
10.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/	43.	ಕೆನ್ಸಿಲ್	/kensIl/
11.	ಚುರ್ಚಿ	/tʃƱrtʃi/	44.	ಕುರ್ಚಿ	/kƱrtʃi/
12.	ಡಾಕ್ಟರ್	/dɔkṭər/	45.	ಚಕ್ರ	/tʃəkra/
13.	ಛತ್ರಿ	/tʃ^{h}ət̪rI/	46.	ಸ್ಕೂಟರ್	/skūṭər/
14.	ಸನುದ್ರ	/sənƱd̪ra/	47.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/
15.	ರಸ್ತೆ	/rəst̪e/	48.	ಶರ್ಟು	/ʃərṭƱ/
16.	ಜಕ್ಷಿ	/dʒəkʃi/	49.	ನಕ್ಷಜ್ರ	/nəkʃədʒra/
17.	ಕ್ಲೇಡು	/klēḍƱ/	50.	ಪೈಕಲ್	/paIkəl/
18.	ಪೋಸ್ಟ್‌ಮಾಕ್ಸ್	/pōsṭmɔks/	51.	ಆಗೋರಿಕ್ಷಾ	/āgōrIkʃa/
19.	ನಿದ್ರೆ	/nId̪re/	52.	ತರ್ಟು	/t̪ərṭƱ/
20.	ಚಂಗ್ರ	/tʃəngra/	53.	ಪ್ರಾಕ್ಷಿ	/prākʃi/
21.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/	54.	ಬಾತ್ರಿ	/bāt̪ri/
22.	ಪಕ್ಷಿ	/pəkʃi/	55.	ಆಸ್ಕತ್ರೆ	/a:skət̪re/
23.	ಬಿತ್ಕೆಟ್	/bIt̪keṭ/	56.	ಚಿಕ್ರ	/tʃIkra/
24.	ಸ್ಲೇಟು	/slēṭƱ/	57.	ಬ್ರಷು	/brəʃƱ/
25.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/	58.	ಸ್ಪೂಟರ್	/spūṭər/
26.	ಸ್ಕೂವು	/skūwƱ/	59.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/
27.	ಪ್ರೇನು	/prēnƱ/	60.	ಸೂರ್ಯ	/sūrja/
28.	ಪೆನ್ಸಿಲ್	/pensIl/	61.	ದ್ರಷು	/d̪rəʃƱ/
29.	ಗ್ನಾನ	/gnāna/	62.	ಪುಸ್ತಕ	/pƱst̪əka/
30.	ಡಾಲ್ಟರ್	/dɔlṭər/	63.	ಬ್ಲೇಡು	/blēḍƱ/
31.	ಇಡ್ಲಿ	/IḍlI/	64.	ರತ್ತ	/rət̪t̪a/
32.	ರಾತ್ರಿ	/rāt̪ri/	65.	ಐಸ್‌ತ್ರೀಂ	/aIst̪rīm/
33.	ಚತ್ರ	/tʃət̪ra/	66.	ಸ್ನಾನ	/snāna/

Stimuli for Articulation Judgment Test for Consonants – Trial 2

Practice Trials

Sl.No.	Stimuli	
	Target (In Kannada)	IPA
1.	ಬೆಕ್ಕು	/bekkʊ/
2.	ಚಪ್ಪವಿ	/tʃəppəvi/

Test Stimuli

S.No.	Stimuli		S.No.	Stimuli	
	In Kannada	IPA		In Kannada	IPA
1.	ಇಟ್ಲಿ	/Iṭll/	34.	ಪೆನ್ಸಿಲ್	/pensIl/
2.	ಚಿಕ್ರ	/tʃIkra/	35.	ಸೂರ್ಲ	/sūrla/
3.	ನಿದ್ರೆ	/nId̪re/	36.	ಹಸ್ತೆ	/həst̪e/
4.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/	37.	ಡಾಲ್ಟರ್	/dɔlṭər/
5.	ಸ್ಲೇಟು	/slēṭʊ/	38.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/
6.	ಪಕ್ಷಿ	/pəkʃi/	39.	ತರ್ಟು	/t̪ərṭʊ/
7.	ಸಮುದ್ರ	/səmʊd̪ra/	40.	ರಕ್ತ	/rəkt̪a/
8.	ಪ್ಲೇಟು	/plēṭʊ/	41.	ಬ್ಲೇಡು	/blēḍʊ/
9.	ಆಸ್ಕತ್ರೆ	/a:skət̪re/	42.	ಸೂರ್ಯ	/sūrja/
10.	ಬಿತ್ಕೆಟ್	/bIt̪keṭ/	43.	ಪುಸ್ತಕ	/pʊst̪əka/
11.	ಸನುದ್ರ	/sənʊd̪ra/	44.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/
12.	ಬಾತ್ರಿ	/bāt̪ri/	45.	ನಿತ್ರೆ	/nIt̪re/
13.	ಪುಕ್ತಕ	/pʊkt̪əka/	46.	ಚತ್ರ	/tʃət̪ra/
14.	ಪ್ರೇನು	/prēnʊ/	47.	ಕ್ಲೇಡು	/klēḍʊ/
15.	ಸ್ಕೂಲು	/skūlʊ/	48.	ಚಕ್ರ	/tʃəkra/
16.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/	49.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/
17.	ಛತ್ರಿ	/tʃʰət̪rI/	50.	ಪ್ರಾಕ್ಷಿ	/prākʃi/
18.	ಐಸ್‌ತ್ರೀಂ	/aIst̪rīm/	51.	ಚಿತ್ರ	/tʃIt̪ra/
19.	ಆಗೋರಿಕ್ಷಾ	/āgōrIkʃa/	52.	ಕ್ಯಾಮರ	/kæməra/
20.	ಚಂಗ್ರ	/tʃəngra/	53.	ರಸ್ತೆ	/rəst̪e/
21.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/	54.	ಸ್ಕೂವು	/skūwʊ/
22.	ಸ್ಕೂಟರ್	/skūṭər/	55.	ಗ್ನಾನ	/gnāna/
23.	ಸ್ನಾನ	/snāna/	56.	ಪೋಸ್ಟ್‌ಮಾಕ್ಸ್	/pōsṭmɔks/
24.	ಸ್ಪೂಟರ್	/spūṭər/	57.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/
25.	ರತ್ತ	/rət̪t̪a/	58.	ಸ್ಯಾಮರ	/sæməra/
26.	ರಾತ್ರಿ	/rāt̪ri/	59.	ಶರ್ಟು	/ʃərṭʊ/
27.	ನಕ್ಷಜ್ರ	/nəkʃədʒra/	60.	ದ್ರಷು	/d̪rəʃʊ/
28.	ಸೈಕಲ್	/saIkəl/	61.	ಇಡ್ಲಿ	/IḍlI/
29.	ಜಕ್ಷಿ	/dʒəkʃi/	62.	ಚಂದ್ರ	/tʃənd̪ra/
30.	ಬ್ರಷು	/brəʃʊ/	63.	ಛಕ್ರಿ	/tʃʰəkrI/
31.	ಚುರ್ಚಿ	/tʃʊrtʃi/	64.	ಡಾಕ್ಟರ್	/dɔkṭər/
32.	ಕುರ್ಚಿ	/kʊrtʃi/	65.	ಟ್ರೇನು	/ṭrēnʊ/
33.	ಪೈಕಲ್	/paIkəl/	66.	ಕೆನ್ಸಿಲ್	/kensIl/

Stimuli for Articulation Judgment Test for Consonants – Trial 3

Practice Trials

Sl.No.	Stimuli	
	Target (In Kannada)	IPA
1.	ಕಿಮಾನ	/kImāna/
2.	ಗಂಟೆ	/gənṭe/

Test Stimuli

Sl.No.	Stimuli		Sl.No.	Stimuli	
	In Kannada	IPA		In Kannada	IPA
1.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/	34.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/
2.	ತರ್ಟು	/t̪ərṭʊ/	35.	ಪ್ರಾಕ್ಷಿ	/prākʃi/
3.	ಜಕ್ಷಿ	/ʤəkʃi/	36.	ಬ್ರಷು	/brəʃʊ/
4.	ಚಂದ್ರ	/tʃənd̪ra/	37.	ದ್ರಷು	/d̪rəʃʊ/
5.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/	38.	ಚಿಕ್ರ	/tʃIkra/
6.	ಸ್ಕೂವು	/skūwʊ/	39.	ಪ್ರೇನು	/prēnʊ/
7.	ಪುಕ್ತಕ	/pʊkt̪əka/	40.	ರಕ್ತ	/rəkt̪a/
8.	ಐಸ್‌ತ್ರೀಂ	/aIst̪rīm/	41.	ಶರ್ಟು	/ʃərṭʊ/
9.	ನಿದ್ರೆ	/nId̪re/	42.	ಪುಸ್ತಕ	/pʊst̪əka/
10.	ಬಾತ್ರಿ	/bāt̪ri/	43.	ಸೂರ್ಯ	/sūrja/
11.	ಇಟ್ಲಿ	/IṭlI/	44.	ರತ್ತ	/rət̪t̪a/
12.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/	45.	ಪೆನ್ಸಿಲ್	/pensIl/
13.	ಕುರ್ಚಿ	/kʊrtʃi/	46.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/
14.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/	47.	ಹಸ್ತೆ	/həst̪e/
15.	ಬ್ಲೇಡು	/blēḍʊ/	48.	ಕ್ಲೇಡು	/klēḍʊ/
16.	ಪೈಕಲ್	/paIkəl/	49.	ಗ್ನಾನ	/gnāna/
17.	ರಸ್ತೆ	/rəst̪e/	50.	ಡಾಲ್ಟರ್	/dɔlṭər/
18.	ಸ್ಪೂಟರ್	/spūṭər/	51.	ಸ್ಕೂಲು	/skūlʊ/
19.	ಸ್ಯಾಮರ	/sæməra/	52.	ಚಂಗ್ರ	/tʃəngra/
20.	ಚತ್ರ	/tʃət̪ra/	53.	ಸೂರ್ಲ	/sūrla/
21.	ರಾತ್ರಿ	/rāt̪ri/	54.	ಸಮುದ್ರ	/səmʊd̪ra/
22.	ಆಸ್ಕತ್ರೆ	/a:skət̪re/	55.	ಪಕ್ಷಿ	/pəkʃi/
23.	ಡಾಕ್ಟರ್	/dɔkṭər/	56.	ಸ್ನಾನ	/snāna/
24.	ಕ್ಯಾಮರ	/kæməra/	57.	ಕೆನ್ಸಿಲ್	/kensIl/
25.	ಸ್ಕೂಟರ್	/skūṭər/	58.	ಸ್ಲೇಟು	/slēṭʊ/
26.	ನಕ್ಷಜ್ರ	/nəkʃəʤra/	59.	ಛಕ್ರಿ	/tʃ^{h}əkrI/
27.	ಬಿತ್ಕೆಟ್	/bIt̪keṭ/	60.	ಚಿತ್ರ	/tʃIt̪ra/
28.	ಪ್ಲೇಟು	/plēṭʊ/	61.	ಚಕ್ರ	/tʃəkra/
29.	ಟ್ರೇನು	/ṭrēnʊ/	62.	ನಿತ್ರೆ	/nIt̪re/
30.	ಚುರ್ಚಿ	/tʃʊrtʃi/	63.	ಸನುದ್ರ	/sənʊd̪ra/
31.	ಛತ್ರಿ	/tʃ^{h}ət̪rI/	64.	ಸೈಕಲ್	/saIkəl/
32.	ಪೋಸ್ಟ್‌ಮಾಕ್ಸ್	/pōsṭmɔks/	65.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/
33.	ಆಗೋರಿಕ್ಷಾ	/āgōrIkʃa/	66.	ಇಡ್ಲಿ	/IḍlI/

III. Articulation Correction Test for: a) Vowels and b) Consonants

1) About the test

The administration of this test is same as that of the Articulation Judgment Test for Vowels and Consonants. In addition, however, the child has to correct the incorrect word stimuli after judging if the spoken item matched the name of the object depicted in the picture. The child has to be instructed to correct the incorrect word and produce the target word correctly. The stimuli for this Articulation Correction Test for Vowels and Consonants are the same as used in Trial 1 of the Articulation Judgment Test for Vowels and Consonants.

2) Instructions

The child is instructed to listen to the word heard through the headphones while he/she is looking at the corresponding picture stimulus kept in front of him/her and judge if the name of the object depicted in the picture was produced correctly or not. The child is instructed to respond after each stimuli by saying "Yes/No" or "Correct/Incorrect (Wrong)". Whenever the child judges a word that is produced as "incorrect/wrong", he/she is instructed to produce the target word correctly.

3) *Scoring*: Responses should be recorded verbatim by the examiner and analyzed as indicated below.

Overall score:

Scores should be offered to the responses of the child as follows:

Score	*Responses*
2	The word was judged correctly by the child and production of target stimulus is accurate
1	The word is judged correctly by the child, but production of target stimulus is inaccurate
0	The word is judged incorrectly by the child or the child produces incorrect response

The maximum possible score is 132 each for vowels and consonants.

Production score:

This has to be carried out on items which receive an overall score of either 1 or 2 as per the scoring procedure indicated above. Scores should be offered to the responses of the child as follows:

Score	*Responses*
1	The child produced the manipulated vowel/consonant in the target word accurately
0	The child did not produce the manipulated vowel/consonant in the target stimuli accurately

Stimuli for Articulation Correction Test for Vowels

Practice Trials

Sl.No.	Stimuli	
	Target (In Kannada)	IPA
1.	ಕಾರು	/kārƱ/
2.	ಗಾಳಿಪಟ	/gāḷIpƱṭa/

Test Stimuli

Sl.No.	Stimuli		Sl.No.	Stimuli	
	In Kannada	IPA		In Kannada	IPA
1.	ಸ್ಕೂಲು	/skūlƱ/	34.	ಸ್ಕೂಟರ್	/skūṭər/
2.	ರುಕ್ತ	/rƱkt̪a/	35.	ಬ್ಲೂಡು	/blūḍƱ/
3.	ಚಕ್ರ	/tʃəkra/	36.	ಸ್ಲೋಟು	/slōṭƱ/
4.	ಸ್ನಾನ	/snāna/	37.	ನಕ್ಷುತ್ರ	/nəkʃƱt̪ra/
5.	ಪುಸ್ತಕ	/pƱst̪əka/	38.	ಕುರ್ಚು	/kƱrtʃʊ/
6.	ಚಕ್ರಿ	/tʃəkri/	39.	ಚಂದ್ರೆ	/tʃənd̪re/
7.	ಐಸ್‌ಕ್ರೂಂ	/aIskrūm/	40.	ಸೈಕುಲ್	/saIkƱl/
8.	ಬಿಸ್ಕುಟ್	/bIskƱṭ/	41.	ಬ್ಲೇಡು	/blēḍƱ/
9.	ಡಾಕ್ಟರ್	/dɔkṭər/	42.	ಸಾರ್ಯ	/sārja/
10.	ಇಡ್ಲು	/IḍlƱ/	43.	ದ್ರಾಕ್ಷ	/d̪rākʃa/
11.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/	44.	ಪಕ್ಷೆ	/pəkʃe/
12.	ಸ್ನೀನ	/snīna/	45.	ಕ್ಯಾಮರ	/kæməra/
13.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/	46.	ಛತ್ರೆ	/tʃʰət̪re/
14.	ರಕ್ತ	/rəkt̪a/	47.	ರಸ್ತೆ	/rəst̪e/
15.	ಪಸ್ತಕ	/pəst̪əka/	48.	ಪೋಸ್ಟ್‌ಬೀಕ್ಸ್	/pōsṭbiks/
16.	ಟ್ರೇನು	/ṭrēnƱ/	49.	ರೂತ್ರಿ	/rūt̪ri/
17.	ಇಡ್ಲಿ	/IḍlI/	50.	ಪೆನ್ಸಿಲ್	/pensIl/
18.	ಕ್ಯಾಮೆರ	/kæmera/	51.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/
19.	ಪೆನ್ಸಲ್	/pensəl/	52.	ಬ್ರಿಷು	/brIʃƱ/
20.	ಆಟೀರಿಕ್ಷಾ	/āṭirIkʃa/	53.	ಬ್ರಷು	/brəʃƱ/
21.	ಚಂದ್ರ	/tʃənd̪ra/	54.	ಚಿತ್ರಿ	/tʃIt̪ri/
22.	ಸ್ಕೀಲು	/skīlƱ/	55.	ಸೂರ್ಯ	/sūrja/
23.	ಡಾಕ್ಟೆರ್	/dɔkṭer/	56.	ಶರ್ಟು	/ʃərṭƱ/
24.	ರಾತ್ರಿ	/rāt̪ri/	57.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/
25.	ಸಮಿದ್ರ	/səmId̪ra/	58.	ಟ್ರೀನು	/ṭrinƱ/
26.	ಛತ್ರಿ	/tʃʰət̪rI/	59.	ಸ್ಲೇಟು	/slēṭƱ/
27.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/	60.	ಚಿತ್ರ	/tʃIt̪ra/
28.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/	61.	ರಸ್ತೊ	/rəst̪o/
29.	ಸ್ಕೂಟುರ್	/skūṭƱr/	62.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/
30.	ಆಸ್ಪಿತ್ರೆ	/a:spIt̪re/	63.	ಸಮುದ್ರ	/səmƱd̪ra/
31.	ಕುರ್ಚಿ	/kƱrtʃi/	64.	ನಿದ್ರೆ	/nId̪re/
32.	ನದ್ರೆ	/nəd̪re/	65.	ಪಕ್ಷಿ	/pəkʃi/
33.	ಶರ್ಟ	/ʃərṭa/	66.	ಸೈಕಲ್	/saIkəl/

Stimuli for Articulation Correction Test for Consonants

Practice Trials

Sl.No	Stimuli	
	Target (In Kannada)	IPA
1.	ತುದುರೆ	/t̪Ʊd̪Ʊre/
2.	ಟೋಪಿ	/ṭōpi/

Test Stimuli

Sl.No.	Stimuli		Sl.No.	Stimuli	
	In Kannada	IPA		In Kannada	IPA
1.	ಪುಕ್ತಕ	/pƱkt̪əka/	34.	ಟ್ರೇನು	/ṭrēnƱ/
2.	ಸೂರ್ಲ	/sūrla/	35.	ಸ್ಕೂಲು	/skūlƱ/
3.	ಪೋಸ್ಟ್ಬಾಕ್ಸ್	/pōsṭbɔks/	36.	ಪ್ಲೇಟು	/plēṭƱ/
4.	ಇಟ್ಲಿ	/IṭlI/	37.	ಸಮುದ್ರ	/səmƱd̪ra/
5.	ನಿತ್ರೆ	/nIt̪re/	38.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/
6.	ಸೈಕಲ್	/saIkəl/	39.	ಸ್ಯಾಮರ	/sæməra/
7.	ಹಸ್ತೆ	/həst̪e/	40.	ಕ್ಯಾಮರ	/kæməra/
8.	ಚಿತ್ರ	/tʃIt̪ra/	41.	ರಕ್ತ	/rəkt̪a/
9.	ಚಂದ್ರ	/tʃənd̪ra/	42.	ಛಕ್ರಿ	/tʃ^{h}əkrI/
10.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/	43.	ಕೆನ್ಸಿಲ್	/kensIl/
11.	ಚುರ್ಚಿ	/tʃƱrtʃi/	44.	ಕುರ್ಚಿ	/kƱrtʃi/
12.	ಡಾಕ್ಟರ್	/dɔkṭər/	45.	ಚಕ್ರ	/tʃəkra/
13.	ಛತ್ರಿ	/tʃ^{h}ət̪rI/	46.	ಸ್ಕೂಟರ್	/skūṭər/
14.	ಸನುದ್ರ	/sənƱd̪ra/	47.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/
15.	ರಸ್ತೆ	/rəst̪e/	48.	ಶರ್ಟು	/ʃərṭƱ/
16.	ಜಕ್ಷಿ	/ʤəkʃi/	49.	ನಕ್ಷಜ್ರ	/nəkʃəʤra/
17.	ಕ್ಲೇಡು	/klēḍƱ/	50.	ಪೈಕಲ್	/paIkəl/
18.	ಪೋಸ್ಟ್ಮಾಕ್ಸ್	/pōsṭmɔks/	51.	ಆಗೋರಿಕ್ಷಾ	/āgōrIkʃa/
19.	ನಿದ್ರೆ	/nId̪re/	52.	ತರ್ಟು	/t̪ərṭƱ/
20.	ಚಂಗ್ರ	/tʃəngra/	53.	ಪ್ರಾಕ್ಷಿ	/prākʃi/
21.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/	54.	ಬಾತ್ರಿ	/bāt̪ri/
22.	ಪಕ್ಷಿ	/pəkʃi/	55.	ಆಸ್ಕತ್ರೆ	/a:skət̪re/
23.	ಬಿತ್ಕೆಟ್	/bIt̪keṭ/	56.	ಚಿಕ್ರ	/tʃIkra/
24.	ಸ್ಲೇಟು	/slēṭƱ/	57.	ಬ್ರಷು	/brəʃƱ/
25.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/	58.	ಸ್ಪೂಟರ್	/spūṭər/
26.	ಸ್ಕೂವು	/skūwƱ/	59.	ಐಸ್ಕ್ರೀಂ	/aIskrīm/
27.	ಪ್ರೇನು	/prēnƱ/	60.	ಸೂರ್ಯ	/sūrja/
28.	ಪೆನ್ಸಿಲ್	/pensIl/	61.	ದ್ರಷು	/d̪rəʃƱ/
29.	ಗ್ನಾನ	/gnāna/	62.	ಪುಸ್ತಕ	/pƱst̪əka/
30.	ಡಾಲ್ಟರ್	/dɔlṭər/	63.	ಬ್ಲೇಡು	/blēḍƱ/
31.	ಇಡ್ಲಿ	/IḍlI/	64.	ರತ್ತ	/rət̪t̪a/
32.	ರಾತ್ರಿ	/rāt̪ri/	65.	ಐಸ್ತ್ರೀಂ	/aIst̪rīm/
33.	ಚತ್ರ	/tʃət̪ra/	66.	ಸ್ನಾನ	/snāna/

IV. Sentence Imitation Test

1) About the test

In this test, the child has to listen to audio recorded sentences that are played one by one through the headphones placed on his/her ears. These recorded sentences are stored on a computer/laptop. There are 20 Kannada sentences with a mean length of utterance ranging from 4 to 7 morphemes.

2) Instructions

The child should be instructed by the examiner to listen to the audio recorded sentences that he/she receives from the earphones. Tell him/her that the sentences are heard one after the other. Instruct the child to repeat or imitate the sentence that he/she hears. If the child says that he/she needs to listen to the sentence once again allow only one repetition of the sentence. Ensure that in instances where the examiner as to present the sentence once again, it is done before the child attempts or responds by repeating or imitating the sentence as per the instruction.

3) Scoring

The responses of the participants should be recorded on a voice recorder by the examiner. The recorded sentences of each child have to be transcribed verbatim by the examiner using broad IPA. While transcribing, the consonants and vowels in the sentences should be marked to facilitate identification of various word shapes and syllable shapes used by the child.

Computation of Word shapes

The total number of words produced by the child in the 20 target sentences put together should be noted first. The total number of different word shapes (bisyllables, trisyllables, four syllables, five syllables, six syllables and seven syllables) produced should be tabulated. Monosyllables, if any, in the imitated sample should be noted separately.

Further, the percentage of each type of word shape produced by the child should be computed using the formula

$$\frac{\text{Number of word shape produced}}{\text{Total number of words produced}} * 100$$

Computation of Syllable shapes

The total number of syllables produced by the child in the 20 target sentences put together should be is noted first. The total number of different syllable shapes (VC, CV, V and CVC) produced should then be tabulated.

If there is any syllable shape in the imitated utterance, in addition to those targeted in the stimuli, should be noted separately (Eg: CVCC, CCV, VCC etc).

In addition, the percentage of each type of syllable shape produced by the child should be computed using the formula

$$\frac{\text{Number of syllable shape produced}}{\text{Total number of syllables produced}} * 100$$

Stimuli for Sentence Imitation Test

Practice Trials

Sl.No.	Stimuli (in Kannada)	Stimuli (in IPA)
1.	ನನಗೆ ಐಸ್ಕ್ರೀಂ ಇಷ್ಟ	/nənəge aIskrīm Iʃṭa /
2.	ನಾನು ಬೆಳಿಗ್ಗೆ ತಿಂಡಿ ತಿಂದೆ	/nānƱ beḷIgge t̪Inḍi t̪Ind̪e/

Test Stimuli

Sl.No.	Stimuli (in Kannada)	Stimuli (in IPA)
1.	ಅಕ್ಕ ಮನೆಗೆ ಹೋದಳು	/əkka mənege hōd̪əḷƱ/
2.	ಮರದ ಮೇಲೆ ಕೋತಿ ಕುಳಿತಿದೆ	/mərəd̪a mēle kōt̪i kƱḷIt̪Id̪e/
3.	ನಾಳೆ ಶಾಲೆಗೆ ರಜೆ ಇದೆ	/nāḷe ʃālege rəʤe Id̪e/
4.	ನಮ್ಮ ಮನೆಯ ಪಕ್ಕದಲ್ಲಿ ಅಂಗಡಿ ಇದೆ	/nəmma məneja pəkkəd̪əlli aŋgəḍi Id̪e/
5.	ನಾಯಿಯು ಕಳ್ಳನನ್ನು ನೋಡಿ ಜೋರಾಗಿ ಬೊಗಳಿತು	/nājIjƱ kəḷḷənənnu nōḍi ʤōrāgi bogəḷIt̪Ʊ/
6.	ಹಕ್ಕಿಗಳು ಆಕಾಶದಲ್ಲಿ ಹಾರುತ್ತಿವೆ	/həkkIgəḷu ākāʃəd̪əlli hārut̪t̪ive/
7.	ಅಮ್ಮ ನನಗೆ ಬಿಸಿಬಿಸಿ ತಿಂಡಿ ಕೊಟ್ಟಳು	/əmma nənəge bIsIbIsI t̪Inḍi koṭṭəḷƱ/
8.	ಕೆಂಪು ಬಣ್ಣದ ಗುಲಾಬಿ ಹೂವು ಚೆನ್ನಾಗಿದೆ	/kempu bəṇṇəd̪a gƱlābi hūvƱ ʧennāgid̪e/
9.	ಆನೆಯನ್ನು ನೋಡಿ ಮಕ್ಕಳು ಚಪ್ಪಾಳೆ ತಟ್ಟಿದರು	/ānejənnƱ nōḍi məkkəḷu ʧəppāḷe t̪əṭṭid̪əru/
10.	ಮಾವಿನ ಹಣ್ಣು ಬಹಳ ರುಚಿಯಾಗಿರುತ್ತದೆ	/māvina həṇṇƱ bəhəḷa ruʧijāgirut̪t̪əd̪e/
11.	ಅಪ್ಪ ನನಗೆ ಹೊಸ ಬಟ್ಟೆ ತಂದರು	/əppa nənəge hosa bəṭṭe t̪ãd̪əru/
12.	ತೋಟದಲ್ಲಿ ಬಣ್ಣದ ಚಿಟ್ಟೆಗಳು ಹಾರಾಡುತ್ತಿವೆ	/t̪ōṭəd̪əlli bəṇṇəd̪a ʧIṭṭegəḷu hārəḍut̪t̪Ive/
13.	ಡಬ್ಬಿಯ ಒಳಗೆ ಗೊಂಬೆ ಇದೆ	/ḍəbbIja oḷəge gombe Id̪e/
14.	ಮೇಜಿನ ಕೆಳಗೆ ಒಂದು ಚಿಕ್ಕ ಬೆಕ್ಕು ಇದೆ	/mēʤIna keḷəge ond̪u ʧIkka bekkƱ Id̪e/
15.	ರೈತರು ಹೊಲದಲ್ಲಿ ಕೆಲಸ ಮಾಡುತ್ತಾರೆ	/rait̪ərƱ holəd̪əlli keləsa māḍut̪t̪āre/
16.	ಪುಟ್ಟಿಗೆ ಅಜ್ಜಿಯ ಕಥೆಗಳು ಇಷ್ಟ	/pƱṭṭIge əʤʤIja kət̪^{h}egəḷƱ Iʃṭa/
17.	ನವಿಲು ಗರಿಗಳು ತುಂಬಾ ಸುಂದರವಾಗಿವೆ	/nəvIlƱ gərIgəḷƱ t̪Ʊmbā sƱnd̪ərəvāgIve/
18.	ಮಳೆ ಬಂದಾಗ ಛತ್ರಿ ಹಿಡಿದು ನಡೆಯಬೇಕು	/məḷe band̪āga ʧ^{h}ət̪ri hiḍid̪u nəḍejəbēku/
19.	ಮಕ್ಕಳು ಮನೆಯ ಮೇಲೆ ಗಾಳಿಪಟ ಹಾರಿಸುತ್ತಿದ್ದಾರೆ	/məkkəḷƱ məneja mēle gāḷipəṭa hārIsƱt̪t̪Id̪d̪āre/
20.	ಊಟ ಮಾಡುವ ಮೊದಲು ಕೈಗಳನ್ನು ತೊಳೆಯಬೇಕು	/ūṭa māḍƱva mod̪əlƱ kaigəḷənnƱ t̪oḷejəbēkƱ/

V. Rapid Automatized Naming (RAN) Test for a) Nouns b) Verbs and c) Size

1) About the test

In this test, arrays of picture stimuli containing colored line drawings representing 'nouns', 'verbs' and 'size' are used. Each array contains a total of 50 items arranged in 5 rows * 10 columns. The picture arrays are first presented to the child to ensure that the child is familiar with each of the test stimuli displayed in the array. For practice trial, the array indicated in the practice trial should be presented to the child. This consists of 12 items (nouns) arranged in 3 rows * 4 columns. Instruct the child to name the pictures one after the other as fast and as accurately as possible. Once the child is familiar with the test procedure, go on to present the test stimuli. Three trials each for RAN Nouns, RAN Verbs and RAN Size should be given. (Refer to picture stimulus arrays for RAN Nouns, RAN Verbs and RAN Size in Appendix 6).

2) Instructions

RAN Nouns

The child should be presented the picture array containing nouns and instructed to name each picture in the array, one after the other, in a sequential manner as fast and as accurately as possible.

RAN Verbs

The child should be presented the picture array containing verbs and instructed to name the action shown in each picture in the array, one after the other, in a sequential manner as fast and as accurately as possible.

RAN Size

The child should be presented the picture array containing an array of pictures of a 'ball' (some big and some small). He/she should be instructed to say whether each picture is 'small' or 'big' as fast and as accurately as possible.

3) Scoring

The examiner should note down the time (in seconds) taken by the child to complete the task in each trial for each of the three tasks.

This will be inclusive of the additional time taken during the process of naming either in instances of self-corrections by the child or if the examiner requests a revision of an incorrectly named stimulus or has to prompt the child to name the stimulus correctly. The total score for each task is obtained by calculating the average time taken in the three trials for the respective tasks.

Appendix 5A

ERROR ANALYSES KEY FOR VOWELS

Sl. No.	Target		Stimuli		Substitution pattern
	In Kannada	IPA	In Kannada	IPA	
1.	ಸ್ನಾನ	/snāna/	ಸ್ನೀನ	/snīna/	/I/-/a/
2.	ಛತ್ರಿ	/tʃ^{h}ət̪rI/	ಛತ್ರೆ	/tʃ^{h}ət̪re/	/e/-/I/
3.	ನಿದ್ರೆ	/nId̪re/	ನದ್ರೆ	/nəd̪re/	/a/-/I/
4.	ಇಡ್ಲಿ	/IḍlI/	ಇಡ್ಲು	/IḍlƱ/	/Ʊ/-/I/
5.	ರಕ್ತ	/rəkt̪a/	ರುಕ್ತ	/rƱkt̪a/	/Ʊ/-/a/
6.	ಚಕ್ರ	/tʃəkra/	ಚಕ್ರಿ	/tʃəkri/	/I/-/a/
7.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/	ದ್ರಾಕ್ಷ	/d̪rākʃa/	/a/-/I/
8.	ರಸ್ತೆ	/rəst̪e/	ರಸ್ತೊ	/rəst̪o/	/o/-/e/
9.	ಚಿತ್ರ	/tʃIt̪ra/	ಚಿತ್ರಿ	/tʃIt̪ri/	/I/-/a/
10.	ಚಂದ್ರ	/tʃənd̪ra/	ಚಂದ್ರೆ	/tʃənd̪re/	/e/-/a/
11.	ಸೂರ್ಯ	/sūrja/	ಸಾರ್ಯ	/sārja/	/a/-/Ʊ/
12.	ರಾತ್ರಿ	/rāt̪ri/	ರೂತ್ರಿ	/rūt̪ri/	/Ʊ/-/a/
13.	ಪಕ್ಷಿ	/pəkʃi/	ಪಕ್ಷೆ	/pəkʃe/	/e/-/I/
14.	ಕುರ್ಚಿ	/kƱrtʃi/	ಕುರ್ಚು	/kƱrtʃʊ/	/Ʊ/-/I/
15.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/	ಆಸ್ಪಿತ್ರೆ	/a:spIt̪re/	/I/-/a/
16.	ಸಮುದ್ರ	/səmƱd̪ra/	ಸಮಿದ್ರ	/səmId̪ra/	/I/-/Ʊ/
17.	ಪುಸ್ತಕ	/pƱst̪əka/	ಪಸ್ತಕ	/pəst̪əka/	/a/-/Ʊ/
18.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/	ನಕ್ಷುತ್ರ	/nəkʃƱt̪ra/	/Ʊ/-/a/
19.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/	ಆಟೀರಿಕ್ಷಾ	/āṭirIkʃa/	/I/-/o/
20.	ಟ್ರೇನು	/ṭrēnƱ/	ಟ್ರೀನು	/ṭrinƱ/	/I/-/e/
21.	ಬ್ಲೇಡು	/blēḍƱ/	ಬ್ಲೂಡು	/blūḍƱ/	/Ʊ/-/e/
22.	ಸ್ಕೂಲು	/skūlƱ/	ಸ್ಕೀಲು	/skīlƱ/	/I/-/Ʊ/
23.	ಬ್ರಷು	/brəʃƱ/	ಬ್ರಿಷು	/brIʃƱ/	/I/-/a/
24.	ಶರ್ಟು	/ʃərṭƱ/	ಶರ್ಟ	/ʃərṭa/	/a/-/Ʊ/
25.	ಸ್ಲೇಟು	/slēṭƱ/	ಸ್ಲೋಟು	/slōṭƱ/	/o/-/e/
26.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/	ಐಸ್‌ಕ್ರೂಂ	/aIskrūm/	/Ʊ/-/I/
27.	ಕ್ಯಾಮರ	/kæməra/	ಕ್ಯಾಮೆರ	/kæmera /	/e/-/a/
28.	ಪೆನ್ಸಿಲ್	/pensIl/	ಪೆನ್ಸಲ್	/pensəl/	/a/-/I/
29.	ಸೈಕಲ್	/saIkəl/	ಸೈಕುಲ್	/saIkƱl/	/Ʊ/-/a/
30.	ಡಾಕ್ಟರ್	/dɔkṭər/	ಡಾಕ್ಟೆರ್	/dɔkṭer/	/e/-/a/
31.	ಸ್ಕೂಟರ್	/skūṭər/	ಸ್ಕೂಟುರ್	/skūṭƱr/	/Ʊ/-/a/
32.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/	ಬಿಸ್ಕುಟ್	/bIskƱṭ/	/Ʊ/-/e/
33.	ಪೋಸ್ಟ್‌ಬಾಕ್ಸ್	/pōsṭbɔks/	ಪೋಸ್ಟ್‌ಬೀಕ್ಸ್	/posṭbiks/	/I/-/a/

Note: In the column for substitution pattern, the vowel on the left is the substituted vowel and the one on the right indicates the target vowel. E.g: /I/-/a/ indicates substitution of /I/ for /a/

Appendix 5B

ERROR ANALYSES KEY FOR CONSONANTS

Sl. No	Target		Stimuli		Substitution pattern		
	In Kannada	IPA	In Kannada	IPA	Place	Manner	Voicing
1.	ಸ್ನಾನ	/snāna/	ಗ್ನಾನ	/gnāna/	Velar-Alveolar	Stop-fricative	V-UV
2.	ಛತ್ರಿ	/tʃ^{h}ət̪rI/	ಛಕ್ರಿ	/tʃ^{h}əkrI/	Velar-Dental	Stops	UV
3.	ನಿದ್ರೆ	/nId̪re/	ನಿತ್ರೆ	/nIt̪re/	Dental	Stops	UV-V
4.	ಇಡ್ಲಿ	/IḍlI/	ಇಟ್ಲಿ	/IṭlI/	Retroflex	Stops	UV-V
5.	ರಕ್ತ	/rəkt̪a/	ರತ್ತ	/rət̪t̪a/	Dental-Velar	Stops	UV
6.	ಚಕ್ರ	/tʃəkra/	ಚತ್ರ	/tʃət̪ra/	Dental - Velar	Stops	UV
7.	ದ್ರಾಕ್ಷಿ	/d̪rākʃi/	ಪ್ರಾಕ್ಷಿ	/prākʃi/	Bilabial - Dental	Stops	UV-V
8.	ರಸ್ತೆ	/rəst̪e/	ಹಸ್ತೆ	/həst̪e/	Glottal -Alveolar	Fricative-Flap	UV-V
9.	ಚಿತ್ರ	/tʃIt̪ra/	ಚಿಕ್ರ	/tʃIkra/	Velar-Dental	Stops	UV
10.	ಚಂದ್ರ	/tʃənd̪ra/	ಚಂಗ್ರ	/tʃəngra/	Velar-Dental	Stops	V
11.	ಸೂರ್ಯ	/sūrja/	ಸೂರ್ಲ	/sūrla/	Alveolar-Palatal	Lateral-Continuant	V
12.	ರಾತ್ರಿ	/rāt̪ri/	ಬಾತ್ರಿ	/bāt̪ri/	Bilabial-Alveolar	Stop-Flap	V
13.	ಪಕ್ಷಿ	/pəkʃi/	ಜಕ್ಷಿ	/ʤəkʃi/	Palatal-Bilabial	Affricate-Stop	V-UV
14.	ಕುರ್ಚಿ	/kƱrtʃi/	ಚುರ್ಚಿ	/tʃƱrtʃi/	Palatal-Velar	Affricate-Stop	UV
15.	ಆಸ್ಪತ್ರೆ	/a:spət̪re/	ಆಸ್ಕತ್ರೆ	/a:skət̪re/	Velar-Bilabial	Stops	UV
16.	ಸಮುದ್ರ	/səmƱd̪ra/	ಸನುದ್ರ	/sənƱd̪ra/	Dental-Bilabial	Nasals	V
17.	ಪುಸ್ತಕ	/pƱst̪əka/	ಪುಕ್ತಕ	/pƱkt̪əka/	Velar-Alveolar	Stop-fricative	UV
18.	ನಕ್ಷತ್ರ	/nəkʃət̪ra/	ನಕ್ಷಜ್ರ	/nəkʃəʤra/	Palatal - Dental	Affricate-Stop	V-UV
19.	ಆಟೋರಿಕ್ಷಾ	/āṭōrIkʃa/	ಆಗೋರಿಕ್ಷಾ	/āgōrIkʃa/	Velar-Retroflex	Stops	V-UV
20.	ಟ್ರೇನು	/ṭrēnƱ/	ಪ್ರೇನು	/prēnƱ/	Bilabial-Retroflex	Stops	UV
21.	ಬ್ಲೇಡು	/blēḍƱ/	ಕ್ಲೇಡು	/klēḍƱ/	Velar-Bilabial	Stops	UV-V
22.	ಸ್ಕೂಲು	/skūlƱ/	ಸ್ಕೂವು	/skūwƱ/	Bilabial-Alveolar	Continuant-Lateral	V
23.	ಬ್ರಷು	/brəʃƱ/	ದ್ರಷು	/d̪rəʃƱ/	Dental-Bilabial	Stops	V
24.	ಶರ್ಟು	/ʃərṭƱ/	ತರ್ಟು	/t̪ərṭƱ/	Dental-Palatal	Stop-Fricative	UV
25.	ಸ್ಲೇಟು	/slēṭƱ/	ಪ್ಲೇಟು	/plēṭƱ/	Bilabial-Alveolar	Stop-Fricative	UV
26.	ಐಸ್‌ಕ್ರೀಂ	/aIskrīm/	ಐಸ್‌ತ್ರೀಂ	/aIst̪rīm/	Dental-Velar	Stops	UV
27.	ಕ್ಯಾಮರ	/kæməra/	ಸ್ಯಾಮರ	/sæməra/	Alveolar-Velar	Fricative-Stop	UV
28.	ಪೆನ್ಸಿಲ್	/pensIl/	ಕೆನ್ಸಿಲ್	/kensIl/	Velar-Bilabial	Stops	UV
29.	ಸೈಕಲ್	/saIkəl/	ಪೈಕಲ್	/paIkəl/	Bilabial-Alveolar	Stop-Fricative	UV
30.	ಡಾಕ್ಟರ್	/dɔkṭər/	ಡಾಲ್ಟರ್	/dɔlṭər/	Alveolar-Velar	Lateral-Stop	V-UV
31.	ಸ್ಕೂಟರ್	/skūṭər/	ಸ್ಪೂಟರ್	/spūṭər/	Bilabial-Velar	Stops	UV
32.	ಬಿಸ್ಕೆಟ್	/bIskeṭ/	ಬಿತ್ಕೆಟ್	/bIt̪keṭ/	Dental-Alveolar	Stop-Fricative	UV
33.	ಪೋಸ್ಟ್ಬಾಕ್ಸ್	/pōsṭbɔks/	ಪೋಸ್ಟ್ಮಾಕ್ಸ್	/pōsṭmɔks/	Bilabials	Nasal-Stop	V

Note: In the columns for substitution of place, manner and voicing, the attribute on the left indicates the substituted feature and the attribute on the right indicates the target. E.g: Stop-fricative indicates substitution of stop for fricative

APPENDIX 7

RESPONSE SHEET

Name:

Age: Gender:

Education:

School:

Medium of instruction in school:

Language/s spoken at home: 1]

2]

Date of testing:

Any other relevant information:

I. Receptive Picture Vocabulary Test

Stimuli No.	Score	Stimuli No.	Score	Stimuli No.	Score
1.		12.		23.	
2.		13.		24.	
3.		14.		25.	
4.		15.		26.	
5.		16.		27.	
6.		17.		28.	
7.		18.		29.	
8.		19.		30.	
9.		20.		31.	
10.		21.		32.	
11.		22.		33.	
				Total Score (33)	

II. Articulation Judgment Test

a) Vowels – Trial 1

Sl.No.	Response	Score	Error pattern	Sl.No.	Response	Score	Error pattern
1.				34.			
2.				35.			
3.				36.			
4.				37.			
5.				38.			
6.				39.			
7.				40.			
8.				41.			
9.				42.			
10.				43.			
11.				44.			
12.				45.			
13.				46.			
14.				47.			
15.				48.			
16.				49.			
17.				50.			
18.				51.			
19.				52.			
20.				53.			
21.				54.			
22.				55.			
23.				56.			
24.				57.			
25.				58.			
26.				59.			
27.				60.			
28.				61.			
29.				62.			
30.				63.			
31.				64.			
32.				65.			
33.				66.			
						Total Score (66)	

a) Vowels – Trial 2

Sl.No.	Response	Score	Error pattern	Sl.No.	Response	Score	Error pattern
1.				34.			
2.				35.			
3.				36.			
4.				37.			
5.				38.			
6.				39.			
7.				40.			
8.				41.			
9.				42.			
10.				43.			
11.				44.			
12.				45.			
13.				46.			
14.				47.			
15.				48.			
16.				49.			
17.				50.			
18.				51.			
19.				52.			
20.				53.			
21.				54.			
22.				55.			
23.				56.			
24.				57.			
25.				58.			
26.				59.			
27.				60.			
28.				61.			
29.				62.			
30.				63.			
31.				64.			
32.				65.			
33.				66.			
						Total Score (66)	

a) Vowels – Trial 3

Sl.No.	Response	Score	Error pattern	Sl.No.	Response	Score	Error pattern
1.				34.			
2.				35.			
3.				36.			
4.				37.			
5.				38.			
6.				39.			
7.				40.			
8.				41.			
9.				42.			
10.				43.			
11.				44.			
12.				45.			
13.				46.			
14.				47.			
15.				48.			
16.				49.			
17.				50.			
18.				51.			
19.				52.			
20.				53.			
21.				54.			
22.				55.			
23.				56.			
24.				57.			
25.				58.			
26.				59.			
27.				60.			
28.				61.			
29.				62.			
30.				63.			
31.				64.			
32.				65.			
33.				66.			
						Total Score (66)	

Qualitative Analysis

i. Number of Vowel Errors w.r.t Tongue Height:

Target words (True words)		Vowels Substituted w.r.t tongue height (Nonwords)		
		Low (a)	Mid (e)	High (I, Ʊ)
	Low (a)		(9) (e-a)	(33) (I-a, Ʊ-a)
	Mid (e, o)	Nil		(12) (I-e, Ʊ-e, I-o)
	High (I, Ʊ)	(18) (a-I, a-Ʊ)	(6) (e-I)	

ii. Number of Vowel Errors w.r.t Tongue Advancement

Target words (True words)		Vowels Substituted w.r.t tongue advancement (Nonwords)		
		Front (I, e)	Central (a)	Back (Ʊ, o)
	Front (I, e)		(9) (a-I)	(21) (Ʊ-I, Ʊ-e, o-e)
	Central (a)	(27) (I-a, e-a)		(15) (Ʊ-a)
	Back (Ʊ, o)	(9) (I-Ʊ, I-o)	(9) (a-Ʊ)	

Note: The values in parenthesis indicate the total number of opportunities available for a particular error pattern in the three trials.

b) Consonants – Trial 1

Sl.No.	Response	Score	Error pattern		
			Place	Manner	Voicing
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					
31.					
32.					
33.					

Sl.No.	Response	Score	Error pattern		
			Place	Manner	Voicing
34.					
35.					
36.					
37.					
38.					
39.					
40.					
41.					
42.					
43.					
44.					
45.					
46.					
47.					
48.					
49.					
50.					
51.					
52.					
53.					
54.					
55.					
56.					
57.					
58.					
59.					
60.					
61.					
62.					
63.					
64.					
65.					
66.					
				Total Score (66)	

b) Consonants – Trial 2

Sl.No.	Response	Score	Error pattern		
			Place	Manner	Voicing
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					
31.					
32.					
33.					

Sl.No.	Response	Score	Error pattern		
			Place	Manner	Voicing
34.					
35.					
36.					
37.					
38.					
39.					
40.					
41.					
42.					
43.					
44.					
45.					
46.					
47.					
48.					
49.					
50.					
51.					
52.					
53.					
54.					
55.					
56.					
57.					
58.					
59.					
60.					
61.					
62.					
63.					
64.					
65.					
66.					
				Total Score (66)	

b) Consonants – Trial 3

Sl.No.	Response	Score	Error pattern		
			Place	Manner	Voicing
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					
31.					
32.					
33.					

Sl.No.	Response	Score	Error pattern		
			Place	Manner	Voicing
34.					
35.					
36.					
37.					
38.					
39.					
40.					
41.					
42.					
43.					
44.					
45.					
46.					
47.					
48.					
49.					
50.					
51.					
52.					
53.					
54.					
55.					
56.					
57.					
58.					
59.					
60.					
61.					
62.					
63.					
64.					
65.					
66.					
				Total Score (66)	

Qualitative Analysis

i. *Number of Consonant Errors w.r.t Place of Articulation*

Target words (True words)		Consonants substituted (Nonwords)						
		Bilabial	Dental	Alveolar	Palatal	Retroflex	Velar	Glottal
	Bilabial		(6)		(3)		(9)	
	Dental	(3)			(3)		(9)	
	Alveolar	(12)	(3)				(6)	(3)
	Palatal		(3)	(3)				
	Retroflex	(3)					(3)	
	Velar	(3)	(9)	(6)	(3)			
	Glottal							

ii. *Number of Consonant Errors w.r.t Manner of Articulation*

Target words (True words)		Consonants substituted with respect to manner of articulation (Nonwords)						
		Stops	Fricatives	Affricates	Nasals	Continuant	Lateral	Flap
	Stops		(3)	(9)	(3)		(3)	
	Fricatives	(18)						
	Affricates							
	Nasals							
	Continuant						(3)	
	Lateral					(3)		
	Flap	(3)	(3)					

iii. *Number of Consonant Errors w.r.t Voicing*

Target words (True words)		Consonants substituted with respect to voicing (Nonwords)	
		Voiced	Unvoiced
	Voiced		(15)
	Unvoiced	(15)	

Note: The values in parenthesis indicate the total number of opportunities available for a particular error pattern in the three trials.

III. Articulation Correction Test

a) Vowels

Sl.No.	Judgment		Correction		Sl.No.	Judgment		Correction	
	Response	Score	Response	Score		Response	Score	Response	Score
1.					34.				
2.					35.				
3.					36.				
4.					37.				
5.					38.				
6.					39.				
7.					40.				
8.					41.				
9.					42.				
10.					43.				
11.					44.				
12.					45.				
13.					46.				
14.					47.				
15.					48.				
16.					49.				
17.					50.				
18.					51.				
19.					52.				
20.					53.				
21.					54.				
22.					55.				
23.					56.				
24.					57.				
25.					58.				
26.					59.				
27.					60.				
28.					61.				
29.					62.				
30.					63.				
31.					64.				
32.					65.				
33.					66.				
								Overall Score (132)	
								Production Score	

b) Consonants

Sl.No.	Judgment		Correction		Sl.No.	Judgment		Correction	
	Response	Score	Response	Score		Response	Score	Response	Score
1.					34.				
2.					35.				
3.					36.				
4.					37.				
5.					38.				
6.					39.				
7.					40.				
8.					41.				
9.					42.				
10.					43.				
11.					44.				
12.					45.				
13.					46.				
14.					47.				
15.					48.				
16.					49.				
17.					50.				
18.					51.				
19.					52.				
20.					53.				
21.					54.				
22.					55.				
23.					56.				
24.					57.				
25.					58.				
26.					59.				
27.					60.				
28.					61.				
29.					62.				
30.					63.				
31.					64.				
32.					65.				
33.					66.				
								Overall Score (132)	
								Production Score	

IV. Sentence Imitation Test

Sl. No.	Response
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	
16.	
17.	
18.	
19.	
20.	

Computation of Word Shapes and Syllable Shapes

	Syllable structure	Target		Response	
		Number	Percentage	Number	Percentage
Word Shapes	Bisyllables	30	33.71		
	Trisyllables	33	37.08		
	Polysyllables • Four syllables • Five syllables • Six syllables • Seven syllables	26 18 5 2 1	29.21 20.22 5.62 2.25 1.12		
	Total	89	-		-
	Monosyllables	-	-		
Syllable shapes	V	10	2.55		
	CV	218	79.27		
	VC	7	3.64		
	CVC	40	14.55		
	Total	275	-		-
	Any other				

V. Rapid Automatized Naming Test

	Time taken (in seconds)			
	Trial 1	Trial 2	Trial 3	Average
Nouns				
Verbs				
Size				

Remarks: