A PRELIMINARY STUDY TO DEVELOP AN ANDROID BASED APPLICATION FOR INTONATION TRAINING IN CHILDREN WITH HEARING IMPAIRMENT

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CERTIFICATE

This is to certify that the dissertation entitled "**A preliminary study to develop an android based application for intonation training in Children with Hearing Impairment**" is a bonafide work submitted in part fulfillment for degree of Master of Science (Speech Language Pathology) of the student Registration Number: **19SLP011**. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that the dissertation entitled "**A preliminary study to develop an android based application for intonation training in Children with Hearing Impairment**" has been prepared under our supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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This is to certify that this dissertation entitled "**A preliminary study to develop an android based application for intonation training in Children with Hearing Impairment"** is the result of my own study under the guidance of Dr. Reuben Thomas Varghese, Scientist-B, Department of Speech-Language Sciences and Co- guidance of Dr. N. Sreedevi, Professor in Speech Sciences, Department of Speech-Language Sciences at All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any other University for award of any other diploma or degree.

Mysuru **Register No**: **19SLP011**

September, 2021

DEDICATED TO MY PARENTS

Acknowledgement

"If you want to know who you are, you have to look at your real self and acknowledge what you see."

I'd want to dedicate my research to my adoring parents and brother.

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Chapter 1

INTRODUCTION

Language is a way in which humans communicate, express their feelings and share their ideas and thoughts (Aristotle,1965). Linguists have identified five basic components of language which includes: phonology, morphology, syntax, semantics, and pragmatics. Phonology is the area of language which contains acoustical characteristics of speech which is further divided into segmental and suprasegmental units (Fromkin et al., 1974). Segmental units include vowels, semi-vowels and consonants and the suprasegmental units include the stress, intonation and juncture features of an utterance (Fry, 1979).

1.1 Suprasegmentals

Human speech is incomplete without the suprasegmental aspect and it is a major ingredient that adds a special kind of flavour to the speech. Suprasegmentals are also known as prosodic features, which consists of intonation, stress, rhythm, tone and juncture. All the suprasegmental features are not limited just only for a single sound instead they are extended over syllables, words and even sentences. Further, the suprasegmentals are also determined by the rate of vibration of the vocal cords, the intensity of the syllable, subglottal pressure, laryngeal adjustment, vocal tract resonance and duration (Liberman et al., 1967).

1.2 Intonation

Intonation may be defined as a "speech melody consisting of different tones" (Seidlhofer, 1994). In American English, intonation referred as a tool which is used to accomplish at least five goals: (a) communicating new information, (b) displaying contrast, (c) expressing meaning, (d) demonstrating pronunciation, and (e) expressing mood or personality. Intonation is not a single system of contours and levels, but it is the product of the interaction between different features of different prosodic systems; tone, pitch-range, loudness, rhythm and tempo (Crystal, 2012).

In English, two major types of intonation are present namely, “peaks” (rising) and “valleys” (falling). Rising type can be seen majorly in questions, while the falling is the most common type of pattern that can be seen in statements, commands and other types of sentences as well. Other types of intonation include; high fall, low fall, fall rise, high rise, midlevel rise, low rise. Intonation has various characteristics which set it apart from other prosodic features, it is meaningful. Other features both prosodic and non-prosodic do not have meaning in themselves they just act as tool to distinguish meaningfully different linguistic items (Fox, 2000).

Children with hearing impairment (CHI) show difficulties in varying their prosodic features during communication. Intonation plays a major role in spoken language and different types of intonation patterns conveys different meaning/emotions such as happy, sad, anger, surprise and request.

1.3 Development of intonation

Intonation is one of the earliest aspects of phonology to develop, children were found to use different pitch directions between 4 and 8 months of age to distinguish early cries (D’Odorico, 1984). Infants respond to suprasegmentals at an early age, possibly at expense of other linguistic features(Crystal, 1973). By 18 months, most of the typically developing children can use intonation patterns produced by adults in their language environment (Menyuk, 1972). By 2 years of age, children have less than 3% error in imitating simple rising and falling inflexion (Kressin et al., 1976). However, the role of intonation in the acquisition of speech and language skills have received relatively less attention. The ability to hear is an important aspect of the development of natural speech. Typically developing children learn to speak by listening to the people around them and they try to imitate the people around them. Normal hearing is crucial to understand the suprasegmentals in speech.

Intonation is studied using pitch contours (Pierre Dellattre, 1966*)*. Studies have reported that pitch is one of the important features affected in CHI (Boothroyd, 1970). CHI lack the conceptual appreciation of what pitch is (Anderson, 1960; Mártony, 1968) and hence they find it difficult to learn intonation patterns while speaking. CHI usually raise their pitch by increasing their intensity (Phillips et al., 1968). Limited pitch variations are seen CHI (Green, 1956; Calvert, 1962; Mártony, 1968; Hood et al.,1969; Horii, 1982; Rosenhouse, 1986; Stathopoulos et al., 1986). Also, severe or unpredictable pitch fluctuations are present (Mártony, 1968; Smith, 1975; Parkhurst et al., 1978; Monsen, 1979) and inappropriate average F0 (Calvert, 1962; Angelocci et al., 1964; Mártony, 1968; Pickett, 1968). In CHI, it appears that rising intonation at the completion of a question is problematic (Phillips et al., 1968; McGarr & Osberger, 1978; Sussman, H., & Hernandez, M., 1979).

1.4 Advancement in technology for speech-language therapy

In recent years we have seen a drastic improvement using technological advancement in the field of speech and hearing. Many android applications are already being used to assist people in their speech therapy. Amid this pandemic it has become difficult to move ahead with traditional or manual mode of therapy and nowadays majority of the patients as well as therapists are preferring tele-mode for their convenience. Various applications are being used in the field of speech and hearing to treat different communication disorders such as, stuttering (Gonçalves et al., 2017), aphasia (Shenoy et al., 2017). However limited applications are being used for training for CHI. Many studies have reported intonation as a factor influencing the perceived intelligibility of deaf speech (Hudgins & Numbers, 1942; McGarr & Osberger, 1978, 1978; Metz et al., 1990; 1978 Monsen, 1978; Smith 1975). Monsen (1978) reported that intonation plays a small but significant role in HI speech intelligibility. Hence, there is an urgent need to develop an android application to facilitate intonation training in hearing-impaired children.

1.5 Need for the study

CHI show difficulty in perception and production of suprasegmentals, studies have reported that suprasegmentals play an important role in the communication abilities of an individual and it is one of the major aspects which adds meaning to their speech. However, the role of intonation in CHI has not received much importance and limited studies have been done, further studies have reported intonation as a factor influencing the perceived intelligibility of deaf speech (Hudgins & Numbers, 1942; McGarr & Osberger, 1978; Metz et al., 1990; Monsen, 1978; Smith & 1975).

Intonation plays a significant role in the intelligibility of hearing impaired speech (1978 Monsen, 1978). Prosodic features are the most affected in hearing impaired individuals, and majority of the time speech and language skills are given more importance, while intonation training is given less importance. Usually, intonation training is given by speech-language pathologist using manual methods and mobile applications are less used for intonation training in CHI. Hence, there is an urgent need to develop an android based application to facilitate intonation training in CHI.

1.6 Aim of the study

The aim of the study was a preliminary attempt to develop an android based application for intonation training in children with hearing impairment.

1.7 Objectives of the study

- To obtain and analyse the intonation patterns using pitch contours produced by typically developing children (TDC) during the production of different sentences embedded with various emotions (anger, happy, sad and request).
- To use the obtained data from TDC to develop an android based application for intonation training in CHI.
- To obtain and analyse the intonation patterns using pitch contours produced by CHI during the production of different sentences embedded with various emotions (anger, happy, sad and request).
- To evaluate the effectiveness of the developed android application in improving the intonation patterns using pitch contours in CHI.

1.8 Clinical Implications

- The developed application will aid in improving intonation in conjunction with normal speech and language therapy.
- The application can be used in real-time across a variety of speech and language disorders in a variety of contexts.
- Tele-practice is much more encouraged during pandemic situations, such mobile applications make learning easier and more pleasant for children.
- The created application is one of the first of its kind to be utilized in Kannada intonation training.

Chapter 2

REVIEW OF LITERATURE

Intonation plays a significant role in improving intelligibility of speech. Impaired suprasegmental features may lead to improper perception/production of words. Acquired hearing loss can hinder with normal speech and language development in children along with this intonation also gets affected. Due to the lack of proper feedback, it is difficult for CHI to understand the different types of intonation which is embedded in their day-to-day communication. CHI are unable to perceive prosodic features through ears accurately, which can be compensated by providing visual cues. Hence, they may rely on visual modality for learning speech-language skills. Suprasegmental features are quite difficult to be taught by traditional way of speech and language therapy, it requires extra effort and subtle changes should be considered.

2.1 Intonation in normal children

Intonation is one of the earliest aspects of phonology to develop, children were found to use different pitch directions between 4 and 8 months of age to distinguish early cries (D’Odorico, 1984). Infants respond to suprasegmentals at an early age, possibly at expense of other linguistic features(Crystal, 1973). By 18 months, most of the typically developing children can use intonation patterns produced by adults in their language environment (Menyuk, 1972). By 2 years of age, children have less than 3% error in imitating simple rising and falling inflexion (Kressin et al., 1976).

2.2 Speech production in CHI

Studies have indicated that only about 20% of the speech output from hearing impaired children is understood by inexperienced listeners (John & Howarth, 1965; JR, 1964; Markides, 1970; Smith, 1975). Speech production in hearing impaired has received much attention over the years, numerous authors have studied the articulatory errors made by CHI and have consistently identified typical articulatory errors such as substitution, omission and distortions (Hudgins & Numbers, 1942; Markides, 1970; Smith,1975).

Hearing impaired children's articulatory errors have received a lot of attention throughout the years. In the research, there appears to be a reasonable amount of consensus that voicing errors and consonant omissions in word-final position are common in hearing impaired speech. Hudgins & Numbers (1942) rated voicing errors as among the most essential to intelligibility. Markides (1970) discovered a link between intelligibility and last consonant omissions. Despite the increased prevalence of this error type, Smith (1975) found only a small association between voicing errors and intelligibility. Substitutions of another vowel with extremely similar articulator location as the intended vowel or replacement of a neutral /a/ or /A/ are common types of vowel mistakes recorded. Consonantal mistakes are claimed to occur more frequently than vowel errors, and they also appear to have a stronger negative connection to intelligibility than vowel errors, at least at first look.

Deaf people's speech is marked by specific timing issues, sluggish speaking, frequent pauses, and poor voice quality. Poor transitions, intonation, and syllables. Excessive and between-word pauses, as well as prolonged duration of both stressed and unstressed sounds, are typically characterised by intrusive positioned pauses inside phrases and sentences. Despite the somewhat inconclusive findings of assessments of speech timing issues, compelling quantitative on correlations of these deaf information is known, little definitive to intelligibility.

Boothroyd et al., (1974), who found substantial gains when their participants were taught to shorten unstressed syllables and within-syllable pauses, were unable to discover a significant increase in intelligibility as a result of these temporal improvements. Levitt et al., (1974) hypothesised a more complicated connection in which intelligibility and pauses and duration of spoken parts interacted.

Hearing impaired children tended to create equal stress on all words in an utterance and pauses between most words, according to prosodic feature production tests. Furthermore, test findings revealed that the youngsters struggled to produce various intonational patterns, notably increasing intonation as in yes/no questions. Monsen & Leiter (1975) attempted to assess intonational variations in deaf participants' speech using narrow-band spectrograms. Despite apparent variations between normal and deaf participants' spectrograms, the investigators were unable to establish a consistent pattern of pitch fluctuation in their subjects that might be linked to impaired intelligibility.

Despite the wide range of voices, there appears to be a vocal quality associated with the hearing impaired. Excessive nasality and incorrect pitch are two of the reasons that contribute to the poor speech quality of hearing impaired. These variables may impair intelligibility, according to some data. According to Stevens et al., (1976), there is a strong link between nasality and decreased intelligibility. McGarr & Osberger (1978) discovered a substantial link between intelligibility and pitch variation from that predicted for an individual's age and sex, albeit it was not a straightforward one. McGarr

& Osberger (1978) discovered a substantial link between intelligibility and pitch variation from that predicted for an individual's age and sex, albeit it was not a straightforward one. Furthermore, it has been discovered that excessive pitch shifts subtract considerably from overall intelligibility (McGarr & Osberger, 1978; Smith, 1975).

2.3 Intonation in CHI

Speech communication in children with severe to profound hearing loss not only lacks the information obtained from others, but also suffers from the poor quality of their own production. Poor auditory feedback in hearing impaired children prohibits the development of speech and language skills, good fluency and their speech is mainly characterized typically by distorted consonants and vowels, incorrect phrase rhythm, and monotone and otherwise inappropriate pitch (Boothroyd et al., 1974). Due to this both intelligibility and naturalness of speech is compromised in CHI as a result they are unable to communicate effectively with family and others.

CHI lack the conceptual appreciation of what pitch is (Anderson, 1960; Mártony, 1968) and hence they find it difficult to learn. CHI usually raise their pitch by increasing their intensity (Phillips et al., 1968). Limited pitch variations are seen CHI (Green, 1956; Calvert, 1962; Mártony, 1968; Hood et al.,1969; Horii, 1982; Rosenhouse, 1986; Stathopoulos et al., 1986). Also, severe or unpredictable pitch fluctuations are present (Mártony, 1968; Smith, 1975; Parkhurst et al., 1978; Monsen, 1979) and inappropriate average F0 (Calvert, 1962; Angelocci et al., 1964; Mártony, 1968; Pickett, 1968). In CHI, it appears that rising intonation at the completion of a question is problematic (Phillips et al., 1968; McGarr & Osberger, 1978; Sussman, H., & Hernandez, M., 1979).

2.4 Treatment strategies for intonation training in various communication disorders

2.4.1 Program for treatment of pitch height in intonation.

Treatment program proposed by Cooper M. (1973).

Individuals with various communication disorders such as motor speech disorders, voice disorders and individuals with hearing impairment can benefit from this technique. It can also be used with normal individuals in order to improve their overall speaking skills or voice quality.

The objectives of the program are to identify a habitual pitch and to improve the production of optimum pitch height.

Procedure:

1. Production of “Uhhuhh” with lips sealed the individual should try to raise the terminal contour while vocalizing spontaneously.
2. The individual can vocalize while keeping the finger on bridge and on the sides of his/her nose for feedback.
3. Natural speech, laughter and some easy words can also be used as an alternative.
4. Clinician can use a tape recorder to provide auditory feedback to the client.
5. Some transitory symptoms may occur while the pitch height is being habituated.
6. Transitory symptoms may include tension under the mandible, in the soft palate, in the sternocleidomastoid muscle, or in the oro-nasopharyngeal region.

7. Clinician can explain that these symptoms are temporary and the client should get accustomed to the new obtained pitch rather than reverting back to the old pitch height.

8. Client can practice with numbers and key words with the new habitual pitch height.

9. Client can produce the optimum pitch height in phrases and short sentences by following the hierarchy:

    - The client can combine a “key word” and a number with short phrases like “Me-me, one, how are you?”

    - The client can answer using the “key word” in a short phrase, e.g., “Me-me, I feel fine”

    - Can repeat the above pattern with different “key word”

10. Reading sentences aloud from using one “key word” for the first set of sentences and can use a different “key word” for the second set of sentences.

11. Client spontaneously talks in sentences but “key word” is used before, during or after each sentence.

12. The client reads aloud selected passages. Clinician provides verbal feedback regarding the pitch height.

13. Clinician and client can converse normally without any “key word” and clinician can provide verbal feedback regarding the pitch height.

Treatment program proposed by Minskoff (1980)

Minskoff (1980), developed another procedure which was used to teach indirect pitch height in children with Learning disability.

The objectives of the program are:

- Discriminate pairs of prosodic stimuli
- Associate appropriate attitude with selected aspects of prosody
- Produce utterances using prosody with different emotions/attitudes
- Produce prosodic patterns that is appropriate to the context.

Techniques such as modelling, minimal pairs, discrimination, imitation and feedback were used to achieve the objectives.

Procedure

1. Clinician presents pairs of speech stimuli that vary in one aspect of prosody. Client's task is to judge the pair as same or different and also, they are encouraged to imitate the pairs. Verbal and visual feedback are provided.
2. The complexity gradually increases, using the following hierarchy;
    - Live stimuli produced by clinician
    - Audio recorded stimuli by clinician and others.
3. Clinician models the utterances with various prosodic patterns to depict a variety of emotions/attitudes and can describe the appropriate situations in which they are used.

4. Client judges the appropriateness of the particular prosodic patterns (For example, the clinician says sadly, “It’s Sunday”, and asks, “Did I sound happy”?)

5. The client tries to convey a selected emotional meaning of neutral statements, such as “that’s my homework”, using different prosodic patterns.

6. The client names the emotion conveyed by prosodic patterns paired with neutral statements.

7. In various situations, the client attempts to identify communication breakdowns caused by inappropriate prosody by noting the misinterpretation or misuse of prosody.

8. The client is presented with examples of sarcasm and teasing which are conveyed by prosody and clinician explains that client should rely on information obtained by prosody when the prosody and the information given do not match.

2.4.2 Program for treatment of direct pitch variation

Pitch variations are targeted directly in disorders such as hearing impairment, dysarthria and voice disorders.

Wilson (1972), developed a program for direct treatment for pitch variation in individuals with hearing impairment.

The objectives are as follows;

- To discriminate among different pitch heights
- Produce speech using an acceptable variety of pitch heights.

Techniques such as modeling, discrimination, singing, use of musical instruments, imitation, gestures, narration, feedback, cues, unison reading, and self-monitoring were used to achieve the objectives.

Procedure:

1. Clinician presents two different prerecorded pitched with varying pitch heights. One stimulus will be in the acceptable pitch height for the client and the other one represents unacceptable pitch height. Verbal feedback is provided.

2. Clinician presents prerecorded high and low pitch heights; client has to discriminate between the two.

3. Clinician presents three different pitch heights (high, mid and low) where in mid-level represents the client's habitual pitch height. Client has to discriminate among the three.

4. Clinician continues to present three different pitch height while gradually decreasing the difference between the pitch heights.

5. Clinician presents the client with two different samples (client's own voice) for discrimination. One sample will be acceptable while the other is not. The comparison will gradually increase from gross to fine and from two variants (high and low) to four variants (very high, high, normal and low).

6. If necessary, clinician can use singing and musical instruments to facilitate discrimination. But the ultimate goal is to improve vocal discrimination.

7. The clinician hums the musical scale upward and downward, client will be asked to imitate the clinician.

8. The clinician hums middle C, B or B flat and client will be asked to keep his or her hand on the clinician’s face or throat. This provides tactile feedback to the client and client can imitate the clinician’s humming.

9. The clinician hums /m/ at the client’s optimum pitch and the client will be asked to produce the following pairs of sounds at the optimum pitch.

    - /m/ - /a/; /m/ - /a/; /ma/
    - /m/-/o/; /m/-/o/; /mo/
    - /m/ - /i/; /m/-/i/; /mi/

10. The client repeats the above steps by increasing the pitch height by one octave.

11. Client attempts to keep a constant pitch height while uttering short sentences at the optimum level.

12. Client repeats the above step by acceptable pitch (pitch variation)

13. If needed clinician can give visual feedback by using a pitch pipe or a pitch meter.

2.4.3 Program for pitch direction in intonation

Moncur et al., (1974), developed a program for direct treatment of pitch direction in individuals with voice disorders.

The objectives are as follows;

- To produce the following pitch direction using selected pitch heights: falling, rising and rising-falling.

Techniques such as drills, contrastive sets, modelling, reading aloud, visual cues and exaggeration were used to achieve the objectives.

Procedure

1. A list of words is given with falling pitch direction and client has to read it aloud while decreasing the loudness. Then client is asked to read another set of words in which falling pitch is produced with increased pitch variation. This is continued until the client is able to produce one-octave drop over a single word.

2. Step 1 is repeated with rising pitch direction and loudness level is decreased during the task.

3. Step 1 is repeated with rising-falling pitch direction. Task can be simplified for the production of rising-falling direction.

4. A set of sentences are given to the client using the words used in step 1 along with-it visual cues are provided. Client has to read aloud each sentence three times using rising, falling and rising-falling pitch.

5. Clinician provides a set of sentences and the client has to read aloud without any visual cues. Client is advised to use any one of the three pitch directions (rising, falling, rising-falling) on the specified word while the pitch direction is not specified.

2.4.4 Approaches to focus directly on Terminal contour

Treatment to improve/focus directly on terminal contour is available for various disorders such as hearing impairment, developmental delay, motor speech disorders, voice disorders and specific language impairment.

Friedman (1985), developed a speech-training program which includes a systemic sequence of training steps along with sensory aids to provide tactile and visual feedback of the contour production.

It uses a hierarchical plan with either a tactile or a visual display of fundamental frequency to improve the remediation of incorrectly produced intonation contours in CHI.

Objectives of the program are as follows:

- To discriminate falling terminal contour on different speech segments with increasing complexity.
- To imitate falling terminal contour on different speech segments with increasing complexity.
- To produce falling terminal contour on different speech segments with increasing complexity.

Procedure

1. The client is asked to discriminate the presence or absence of falling terminal contour in either the clinician or client's speech using stimuli, that get increasingly complicated. Clients are permitted to wear hearing aids for this step. The hierarchy of stimulus are as follows;

    a) Vowels in isolation

    b) CV syllables and/or disyllable CV stimuli with falling terminal contour is on the first or the second syllable

    c) Three CV syllable of long-long-long duration

d) Three CV syllables of long-short-long duration

e) Three CV syllables of short-short-short duration

f) Three syllable phrases (real words)

g) Two syllable phrases (real words)

h) One syllable phrases (real words)

2. Clinician can use vibrotactile feedback and cues, visipitch and additional sensory cues. Clinician fades the cues as the client progresses.

3. Client produces falling terminal contours using the hierarchy given in step 1. Clinician can use cues and feedback to prompt an acceptable production but fades them out as quickly as possible.

2.4.5 Program for teaching several aspects of Intonation

Dworkin (1991), provided a treatment guide for individuals with motor-speech disorder.

The program's main goal is to read out loud phrases that indicate requests for information in an international context.

Techniques such as cues, reading aloud, auditory and verbal feedback, negative practice were used to achieve the objective.

Procedure

1. To indicate pitch height, the clinician creates index cards with the digits one to three. The sentences have “wh” questions with an increasing pitch height nucleus, and a decreasing terminal contour. Example: What did you say a moment ago?

3 Say

2 What did you

1 A moment ago?

2. The client's performance is audiotaped by the clinician so that he or she may discuss it.

3. The client reads the sentences from step 1 aloud

4. To emphasise the importance of intonation in interpretation, the client reads the lines from step 1 aloud again, but this time using the "wrong" pitch heights.

This program targets nucleus, terminal contour, and overall contour.

In the literature, various approaches for training/correcting intonation have been given. These, on the other hand, have all been advocated for Western languages, especially English. It's possible that the concepts behind the teaching of intonation in people with communication disorders haven't changed. However, the techniques may not work for Indian languages since the linguistic structure and intonation patterns are different.

Furthermore, the dialects within the language demand a unique approach to developing a training plan for the underserved. All of the therapy plans listed above are conventional and are carried out manually by clinician.

2.5 Use of mobile applications in the treatment of various communication disorders

In the recent years we can see that there is an exponential growth in the usage of mobile apps (android/iOS) in the field of Speech and Hearing to aid children/adults with communication disorders. There are many dedicated applications for various disorders such as autism, apraxia, stuttering, aphasia and for articulation disorders and these can be used across any age group. In this pandemic situation it is difficult to avail speech therapy in person and with applications like these, patients can continue their therapies from home while staying connected to a speech and language therapist.

2.6 Use of mobile applications in the intervention of Persons with Stuttering

Children who stutter are more likely to experience negative attitudes towards communication (Agius, 2015). Negative attitude towards own speech may result in poor self-esteem, poor interpersonal communication.

"Think Smart, Feel Smart Program" (Agius, 2015) the author wanted to explore the changes in the feeling and attitudes of thirty school-age children who stutter. The aim was to investigate shifts in the feelings and attitudes of school-age children who stutter following a ten-week thinking skills program based on creativity activities, the results of this study led to the development "The Fluency Smart Intervention Strategy (SIS)" an iOS-based application which can be used by Speech-Language Pathologists and students when working with school age children who stutter in the age range of 8-12 years. The SIS consists of four components and includes different activities. The four components are,

a) Think Smart, Feel Smart
b) Cool Speech

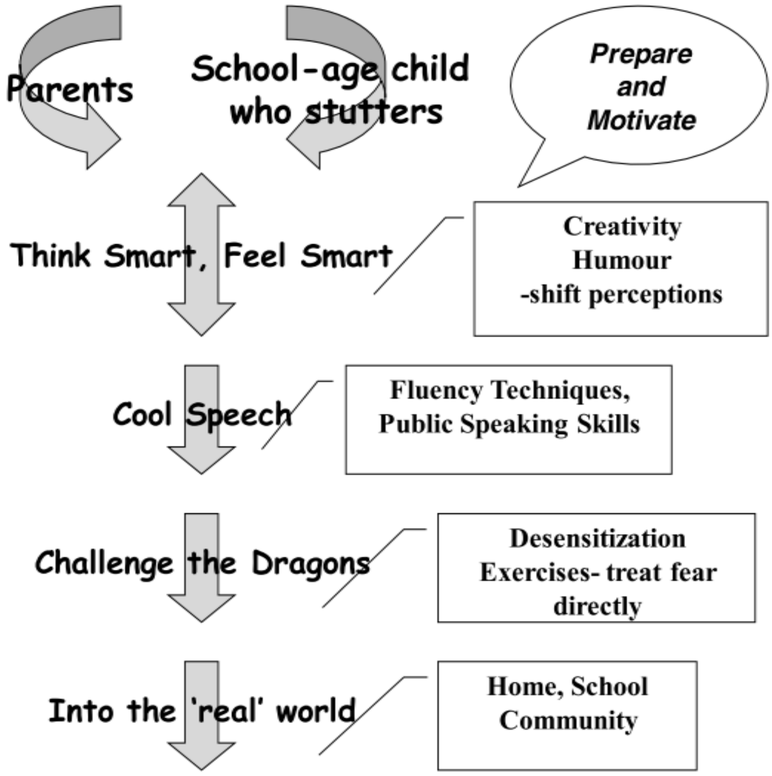
c) Challenge the Dragons and,

d) Into the 'Real' World.

Figure 2.1 depicts an overview of the Smart Intervention Strategy (SIS) for school-age children who stutter (Agius, 2015).

Figure 2.1

Pictorial representation of the treatment strategy



The application has been downloaded in fifteen countries and many people have found it useful and much more interesting to use with children.

2.7 Use of mobile applications in the intervention of Persons with Aphasia

Tactus Therapy is a paid mobile/tablet application which is available for both iOS and android. It covers adult disorders like Aphasia, Apraxia, Dysarthria, Dysphagia and other Cognitive disorders. The app comes in five different languages.

An independent study was conducted by Dr. Brielle Stark & Elizabeth Warburton at the University of Cambridge in England (2016). The aim was to study the effectiveness and feasibility of self-delivered and directed iPad-based speech therapy in patients with chronic aphasia following a left MCA-territory stroke. The app used was called as Language Therapy by Tactus Therapy. The app was created by a speech and language therapist and provided four categories for study: Reading, Naming, Comprehension and Writing. The participants who were recruited for the study was diagnosed with Aphasia and was living with Aphasia since a year. All the participants were encouraged to use the application for about 20 minutes a day for 4 weeks. Every single patient showed some improvement.

2.8 Use of mobile applications in the intervention of Persons with Hearing impairment

Many mobile applications can be used to ease up the day-to-day communication for hearing impaired individuals. Apps such as google live transcribe, rogervoice, voxsci helps in converting speech to text so that HI individuals can communicate better without much difficulty. There are several other applications which helps in alerting the individuals with tactile vibrations to check their notification or even door bells. Few applications help in building up the vocabulary in CHI and help in improving speech and language skills. Limited number of applications are available to improve intonation in CHI.

Chapter 3

METHOD

The objectives of the study are as follows;

- To obtain and analyse the intonation patterns using pitch contours produced by typically developing children (TDC) during the production of different sentences embedded with various emotions (anger, happy, sad and request).
- To use the obtained data from TDC to develop an android based application for intonation training in CHI.
- To obtain and analyse the intonation patterns using pitch contours produced by CHI during the production of different sentences embedded with various emotions (anger, happy, sad and request).
- To evaluate the effectiveness of the developed android application in improving the intonation patterns using pitch contours in CHI.

All procedures done in the study were adhering to the ethical standards of the institutional review board and approval was taken priorly.

3.1 Study Design

Standard group comparison.

3.2 Characteristics of participants

In the present study, we considered two groups of participants. Group I included five TDC with normal hearing, vision, speech and language skills with mean age range of 5 years (*SD* =0.56), and Group II consisted of five CHI with mean age of 4.84 years (*SD*= 0.27). all the participants in Group II were diagnosed with bilateral severe to profound sensorineural hearing loss and Kannada as their native language.

Inclusionary Criteria for Group I (TDC):

- Should have normal/corrected vision
- Normal speech, language and cognitive abilities.
- Age-matched with group II (CHI).

Inclusionary Criteria for Group II (CHI):

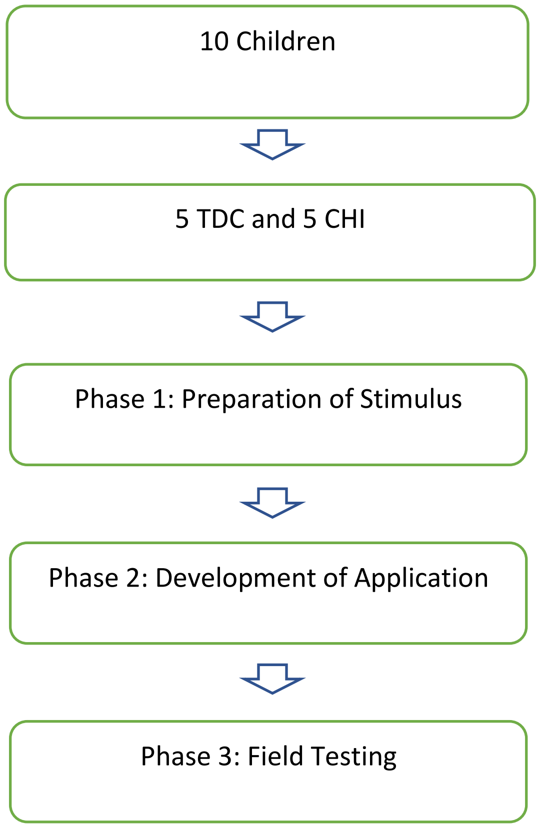
- Children who are diagnosed with bilateral severe to profound sensorineural hearing loss and using hearing aid regularly
- Children should have receptive, expressive language skills within the age range of 3-6 years which is determined using the Assessment Checklist for Speech-Language Skills
- Should have attended at least 6 months of regular speech therapy
- Normal/corrected vision
- Native Kannada speaker.

Exclusionary Criteria:

- Any co-morbid conditions, neurological, psychological or visual deficits along with hearing impairment,
- Language age is less than three years.

3.3 Procedure

Before the initiation of the study, the aim and the objectives were informed to the parents and written consent was taken from the parents. The study was divided into three phases.



Phase 1: Preparation of the stimulus.

Ten commonly used Kannada sentences with four emotional variations (anger, happy, sad and request) used by children in daily communication was prepared using previous projects, studies and by consulting other experienced Speech and Language Pathologists and Special Educators, taking age and socio-cultural norms into consideration. The stimulus was given to three experienced Speech and Language Pathologists for content validation. The final stimulus set was prepared after incorporating the suggestions and modifications given by the Speech and Language Pathologists and Special Educators.

Phase 2: Development of an application for intonation training.

Developing the android application and creating a database for intonation training was done with the help and consultation from an application developer and inputs were given by the researcher. First, the waveforms of the ten sentences were extracted using Praat software and then they were incorporated into the application wherein the sentences were displayed along with the extracted waveforms. A database for normal intonation scores and contours was created by collecting the recorded responses of the finalized sentences from five typically developing children.

Each of the finalized stimulus was displayed on the mobile screen along with the waveforms and with appropriate emojis which was depicting the emotion of the particular sentences. An audio recorded version of the same stimulus can be played using the play button. The participants were instructed to listen to the audio and record each of the sentences using the record button which was displayed on the screen. This served as a baseline.

Phase 3: Field testing.

Field testing the developed android application on CHI. Parents were educated regarding the use of the application and they were instructed to use it for intonation training for children on a day-to-day basis.

i. Pre-test phase: The application was field-tested on CHI the same procedure which was followed in TDC was used. The data obtained served as a baseline.
ii. Training phase: In this phase, children were trained using the application for a month (minimum of 5-10 sessions). First, the target stimulus was displayed on the screen and the participant had to match his/her intonation contour to the target contour. Each of the stressed word/words in a sentence were highlighted and appropriate cues was given to improve the correct production of the sentences.
iii. Post-test phase: After undergoing the training phase, a post-test was carried out to analyse the intonation contour for CHI. The obtained results were compared

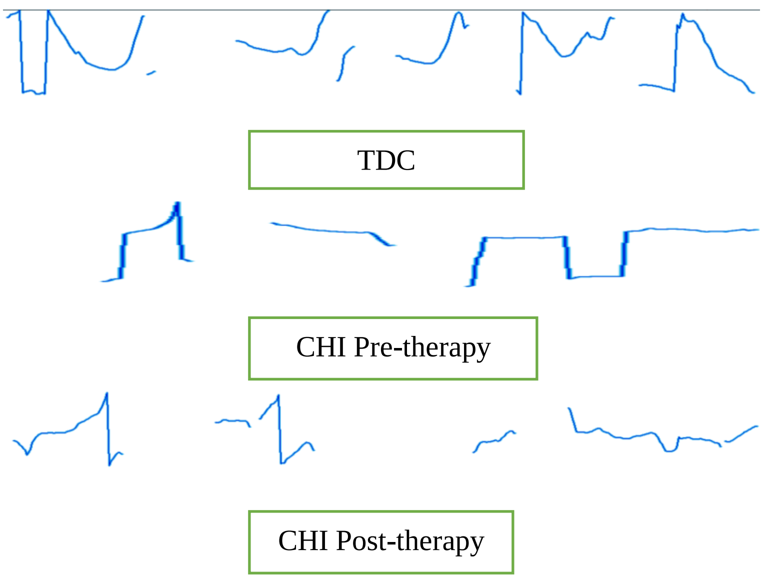
with the baseline results of CHI to check for the variations. This helped in finding the effectiveness of the developed application for improving intonation in CHI.

Waveform of each individual from both the groups for all the sentences with different emotions was extracted using Praat Software. The below figures represent the waveforms of different emotions.

Waveforms obtained for different emotions such as anger, happy, sad and request are depicted in figure 3.1, 3.2, 3.3 and 3.4 respectively.

Figure 3.1

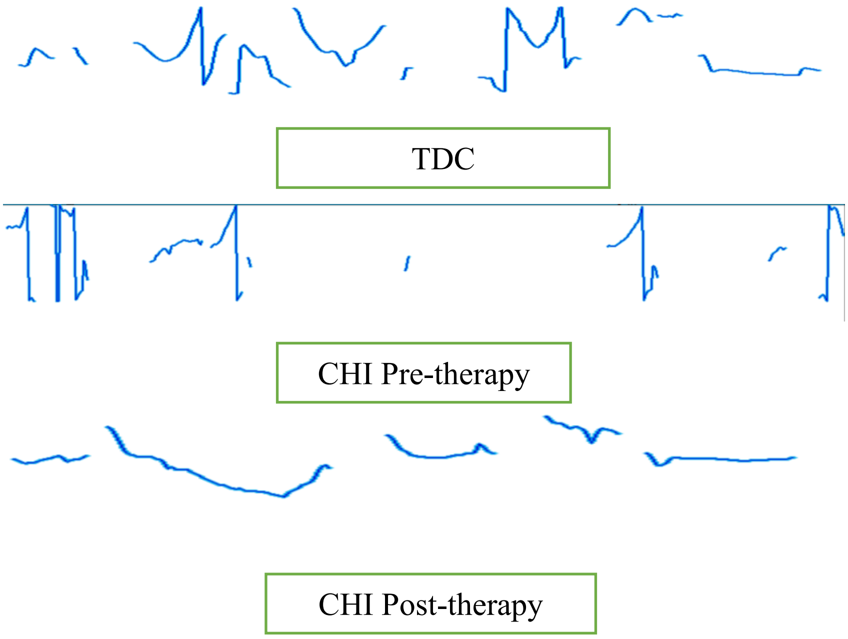
Waveform obtained for "anger" emotion.



Am'ma ṭivi āph māḍbiḍa

Figure 3.2

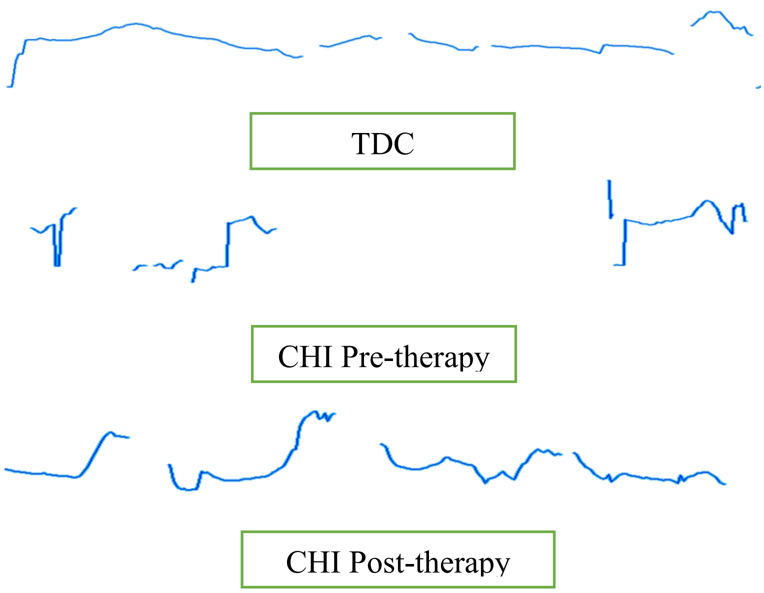
Waveform obtained for "happy" emotion.



ˈtiːtʃə Nanagē stɑː koṭru

Figure 3.3

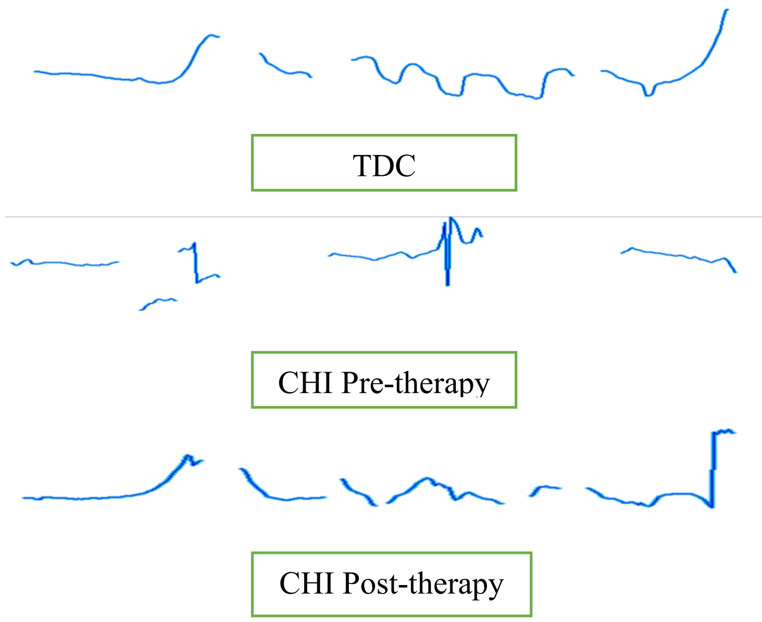
Waveform obtained for "sad" emotion.



Nanna bāl ondu huḍuga tagoṇḍa

Figure 3.4

Waveform obtained "request" emotion.

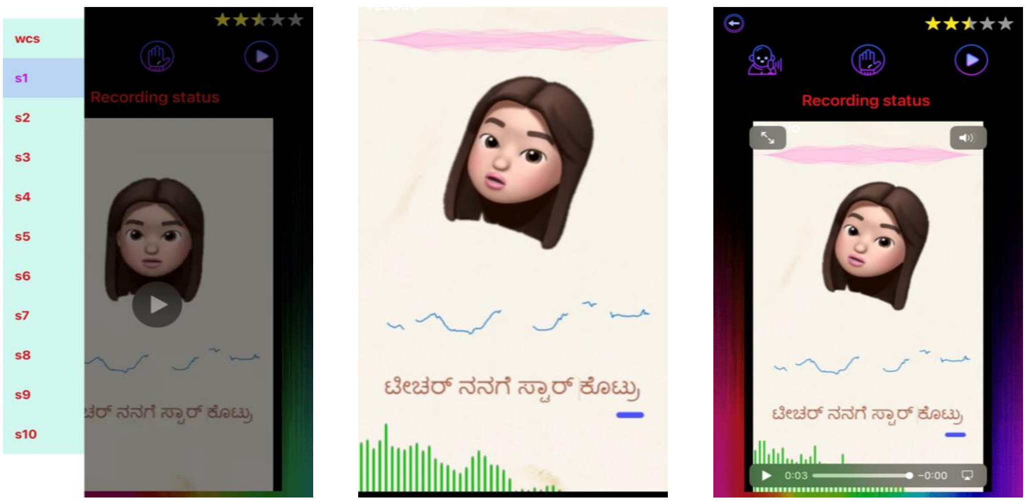


Tātā vākke karkoṇḍ hōgi

The pictures given in figure 3.5 represents the working model of the android application where in picture 1 represents stimulus selection screen, 2 and 3 depicts the play and record screen respectively.

Figure 3.5

Working model of the application



1 2 3

3.4 Data Recording

The recoding was carried out in a noise-free room. The participants were instructed to sit with their caregiver and carry on with the recording. Different stimulus can be selected in the selection screen, participants were advised to listen to the ongoing stimulus and record their sample using the record option provided in the application. After the recording all the samples were converted into .wav format for further analysis.

3.5 Statistical Analysis

The obtained parameters were tabulated and subjected to statistical analysis in Statistical Package for the Social Sciences (SPSS) software (Version 21.0). Descriptive statistics was carried out to obtain the mean, median, and standard deviation for both the groups. As the obtained data was not following normal distribution, non-parametric tests, Wilcoxon signed ranked test was carried out to compare across group II CHI pre-therapy vs CHI post-therapy, while Mann-Whitney test was administered to compare TDC vs CHI pre-therapy as well as TDC vs CHI post-therapy.

Chapter 5

RESULTS

The present study investigated the production of intonation and pitch contours of different sentences embedded with emotional variations (anger, happy, sad and request) in TDC, CHI pre-therapy and CHI post-therapy.

The obtained values were tabulated and subjected to statistical analysis to achieve the objectives of the study:

a) To obtain and analyse the intonation patterns using pitch contours produced by typically developing children (TDC) during the production of different sentences embedded with various emotions (anger, happy, sad and request).
b) To use the obtained data from TDC to develop an android based application for intonation training in CHI.
c) To obtain and analyse the intonation patterns using pitch contours produced by CHI during the production of different sentences embedded with various emotions (anger, happy, sad and request).
d) To evaluate the effectiveness of the developed android application in improving the intonation patterns using pitch contours in CHI.

4.1 To obtain and analyse the intonation patterns using pitch contours produced by typically developing children (TDC) during the production of different sentences embedded with various emotions (anger, happy, sad and request).

Intonation contours for different sentences with various emotions for TDC were obtained priorly to the development of the application. Intonation contours are shown in figure 4.1. We can observe that rise-fall type of contour was seen more in sentences with “request” emotion and flat type was seen more in sentences with “happy” emotion as compared to other emotions. Along with this mean F0, minimum F0 and maximum F0 are tabulated in table 4.1. As observed mean F0, minimum F0 and maximum F0 are found to be higher in sentences with "happy" emotion as compared to other emotions.

Figure 4.1

Intonation contours for various emotions in TDC

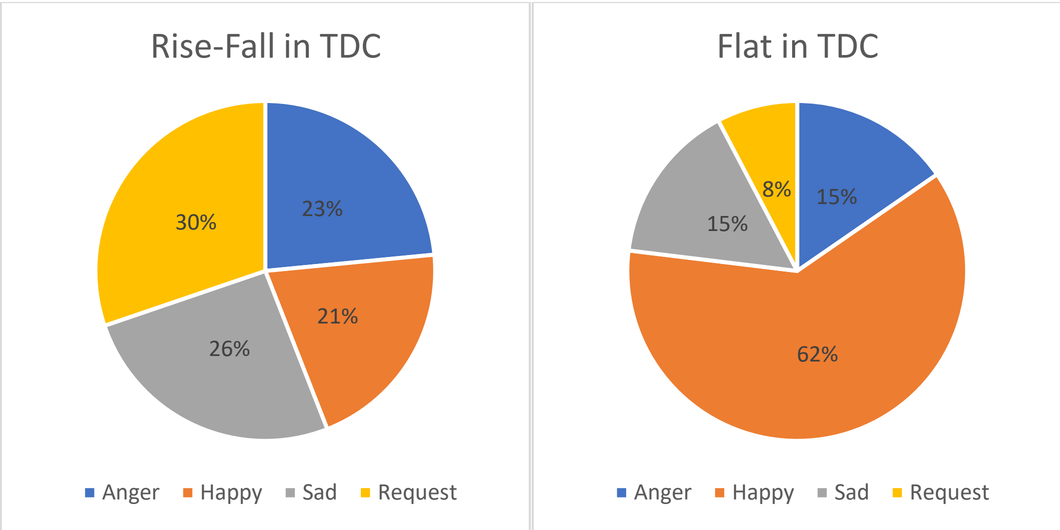


Table 4.1

Mean F0, minimum F0 and maximum F0 for TDC group

			TDC			
Emotion	**MeanF0**	**SD**	**Min F0**	**SD**	**Max F0**	**SD**
Anger	324.68	40.07	222.55	14.03	446.74	61.65
Happy	336.66	18.42	224.18	34.05	473.13	59.86
Sad	323.36	27.29	189.55	35.63	464.22	47.77
Request	324.30	34.72	211.60	34.75	452.42	52.78
Total F0	326.74	30.98	214.08	14.67	456.65	53.36

4.2 To use the obtained data from TDC to develop an android based application for intonation training in CHI.

Before developing the application, intonation and pitch contours was obtained from TDC and the recordings for all ten sentences was done with various emotions (anger, happy, sad and request). The data obtained from TDC was considered as a baseline.

The development of application was divided into three phases:

a) Preparation of stimulus: Ten commonly used Kannada sentences with four emotional variations (anger, happy, sad and request) used by children in daily communication was prepared using previous projects, studies and by consulting other experienced Speech and Language Pathologists and Special Educators, taking age and socio-cultural norms into consideration.

b) Development of application: First the waveforms of all the sentences was extracted using Praat software. Each of the finalized stimulus was displayed on the mobile screen along with the waveforms and with appropriate emojis which was depicting the emotion of the particular sentences. An audio recorded version of the same stimulus can be played using the play button.

c) Field testing: The application was field-tested on CHI the same procedure which was followed in TDC was used. The data obtained served as a baseline. Later CHI group underwent intonation training for over a month (5-10 session) and were trained using the application. After the training phase post-therapy recording was done to check the progress in CHI group, this was compared with the pre-therapy recordings.

4.3 To obtain and analyse the intonation patterns using pitch contours produced by CHI during the production of different sentences embedded with various emotions (anger, happy, sad and request).

Intonation contours for different sentences with various emotions for CHI pre-therapy were obtained. Intonation contours are shown in figure 4.2. We can observe that rise-fall type of contour was seen more in sentences with “anger and happy” emotion and flat type was seen more in sentences with “request and sad” emotion as compared to other emotions. Along with this mean F0, minimum F0 and maximum F0 are tabulated in table 4.2. As observed mean F0 was found to be higher in sentences with “happy” emotion, minimum F0 was higher in sentences with “sad” emotion and maximum F0 was found to be higher in sentences with “request” emotion as compared to other emotions.

Figure 4.2

Intonation contours for various emotions in CHI pre-therapy.

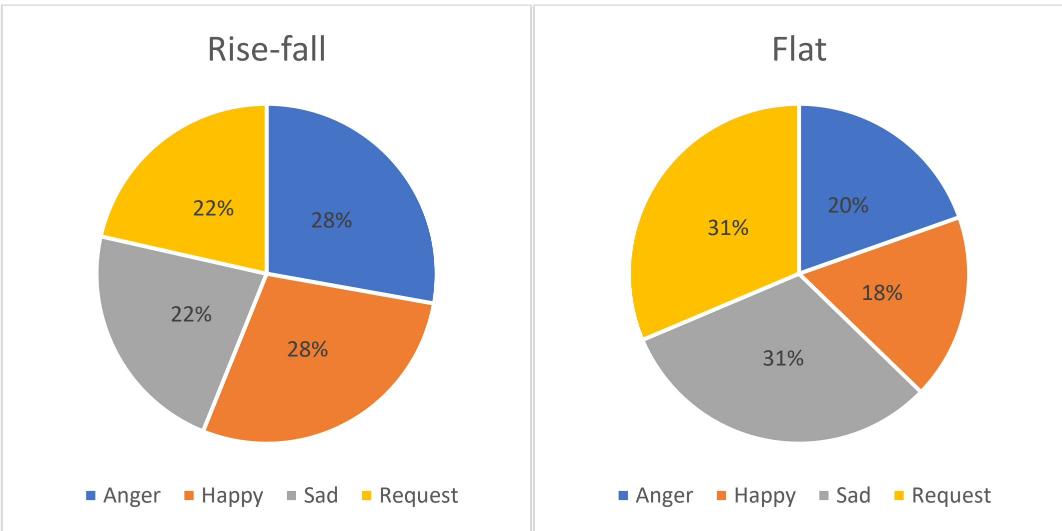


Table 4.2

Mean F0, minimum F0 and maximum F0 for CHI pre-therapy.

			CHI pre-therapy			
Emotion	**MeanF0**	**SD**	**Min F0**	**SD**	**Max F0**	**SD**
Anger	310.90	30.18	166.22	48.15	438.12	87.95
Happy	323.14	39.79	176.91	24.56	458.11	52.41
Sad	305.60	60.58	187.76	60.32	422.43	87.41
Request	319.93	33.99	179.73	26.56	458.50	82.36
Total F0	314.09	36.37	175.37	32.45	443.06	77.20

4.4 To evaluate the effectiveness of the developed android application in improving the intonation patterns using pitch contours in CHI.

Intonation contours for different sentences with various emotions for CHI post-therapy were obtained. Intonation contours are shown in figure 4.3. We can observe that rise-fall type of contour was seen more in sentences with “anger and happy” emotion and flat type was seen more in sentences with “sad” emotion as compared to other emotions. Along with this mean F0, minimum F0 and maximum F0 are tabulated in table 4.3. As observed mean F0, minimum F0 and maximum F0 was found to be higher in sentences with “request” emotion as compared to other emotions. Wilcoxon signed rank test was carried out to assess the progress the results are tabulated in table 4.4. Results revealed that there was no significant difference found between the groups *(/z/=0, p=1)*. Mann-Whitney test was carried out to assess TDC vs CHI pre-therapy *(/z/=0.522, p= .602)* and TDC vs CHI post-therapy *(/z/=0.731, p= 0.465)* and the results are tabulated in table 4.5 and 4.6 respectively. Results revealed that there was no significant difference between the groups.

Figure 4.3

Intonation contours for various emotions in CHI post-therapy.

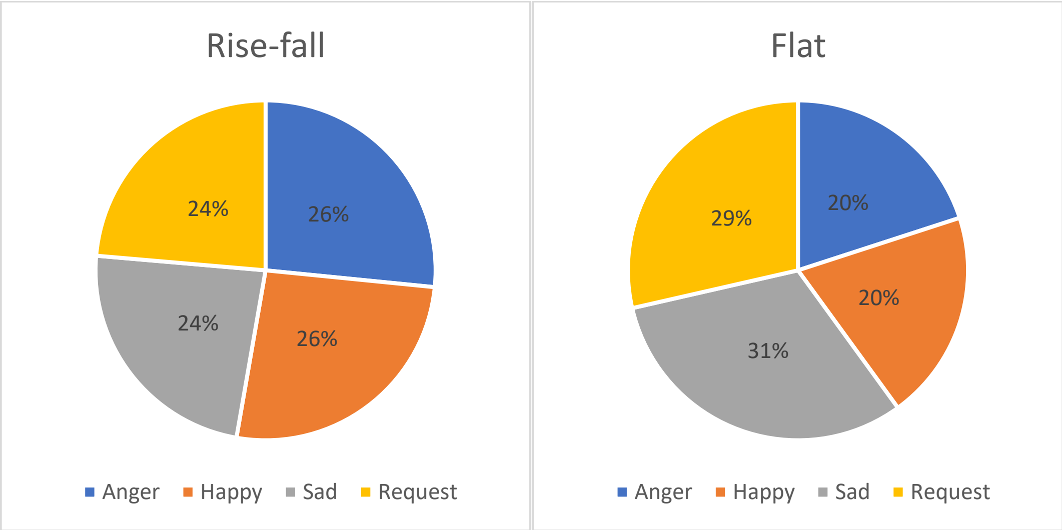


Table 4.3

Mean F0, minimum F0 and maximum F0 for CHI post-therapy.

	CHI post-therapy					
Emotion	**MeanF0**	**SD**	**Min F0**	**SD**	**Max F0**	**SD**
Anger	308.77	32.26	159.13	37.85	427.58	61.79
Happy	314.87	44.91	177.71	24.07	430.62	67.75
Sad	316.65	52.75	166.42	38.03	420.94	86.80
Request	319.74	35.06	183.59	12.45	467.95	72.87
Total F0	313.76	37.65	169.19	24.21	434.93	62.82

Table 4.4

Comparison of mean F0 for CHI pre-therapy vs CHI post-therapy.

Emotion	/z/	*p*
Anger	0.365	0.715
Happy	1.461	0.144
Sad	1.095	0.273
Request	0.365	0.715
Total F0	0.000	1

Table 4.5

Comparison of mean F0 for TDC vs CHI pre-therapy.

	TDC vs CHI pre-therapy	
Emotions	**/z/**	***p***
Anger	0.522	0.602
Happy	0.731	0.465
Sad	0.522	0.602
Request	0.313	0.754
Total F0	0.522	0.602

Table 4.6

Comparison of mean F0 for TDC vs CHI post-therapy.

	TDC vs CHI post therapy	
Emotions	**/z/**	***p***
Anger	0.522	0.602
Happy	0.731	0.465
Sad	0.104	0.917
Request	0.522	0.602
Total F0	0.731	0.465

Chapter 5

DISCUSSION

The present study was carried out with the objective of developing an android application for intonation training in CHI. A database was created after obtaining the intonation patterns and pitch contours obtained from TDC. Recordings of all ten sentences embedded with various emotions such as anger, happy, sad and request was done. Later the application was used on CHI to obtain a baseline before starting intonation training. CHI group underwent intonation training for over a month (5-10 session) along with regular speech-language and auditory verbal therapy sessions. Post-therapy recordings revealed that there was an improvement seen in the perception and production of the stimulus.

The purpose of this study is to address the following questions:

a) To obtain and analyse the intonation patterns using pitch contours produced by typically developing children (TDC) during the production of different sentences embedded with various emotions (anger, happy, sad and request).

b) To use the obtained data from TDC to develop an android based application for intonation training in CHI.

c) To obtain and analyse the intonation patterns using pitch contours produced by CHI during the production of different sentences embedded with various emotions (anger, happy, sad and request).

d) To evaluate the effectiveness of the developed android application in improving the intonation patterns using pitch contours in CHI.

5.1 To obtain and analyse the intonation patterns using pitch contours produced by typically developing children (TDC) during the production of different sentences embedded with various emotions (anger, happy, sad and request).

Intonation and pitch contours for different sentences with various emotions for TDC were obtained priorly to the development of the application. The researcher was mainly focusing on the occurrence of "rise-fall" and "flat" type of intonation contours in the stimulus. Results revealed that rise-fall type of contour was seen more in sentences with "request" emotion and flat type was seen more in sentences with "happy" emotion as compared to other emotions.

5.2 To use the obtained data from TDC to develop an android based application for intonation training in CHI.

Due to the pandemic situation, developed application was used for intonation training in CHI during tele-therapy, along with their regular speech-language and auditory verbal therapy. Traditional techniques for training intonation were also incorporated in the sessions. The application had a major role in providing visual and auditory feedback to the participants, this might have facilitated in the perception and production of different emotions.

5.3 To obtain and analyse the intonation patterns using pitch contours produced by CHI during the production of different sentences embedded with various emotions (anger, happy, sad and request).

Intonation contours for different sentences with various emotions for CHI pre-therapy were obtained. It is observed that rise-fall type of contour was seen more in sentences with "anger and happy" emotion and flat type was seen more in sentences with "request and sad" emotion as compared to other emotions.

The acoustic parameters of the “happy” emotion has an increased intensity, broader pitch range, and higher pitch fluctuation (Luo et al., 2016; Arnott, 1993) and might have resulted in the proper judgement of emotion by CHI. The acoustic properties of the “sad” emotion include a smaller pitch range, lower pitch fluctuation, and decreased intensity (Luo et al., 2016). A study done by Yildirim et al., (2004) revealed that “sad and neutral” emotion also shared similar acoustical properties. Hence the results of the present study are in consensus with previous studies.

5.4 To evaluate the effectiveness of the developed android application in improving the intonation patterns using pitch contours in CHI.

Intonation contours for different sentences with various emotions for CHI post-therapy were obtained. It is observed that rise-fall type of contour was seen more in sentences with “anger and happy” emotion and flat type was seen more in sentences with “sad” emotion as compared to other emotions. As referred in the previous section “happy” emotion had higher pitch fluctuations, broader pitch range and increased intensity, while “sad and neutral” emotions had lower pitch fluctuations, smaller pitch range and reduced intensity. This might have facilitated in the perception and production of all the sentences with multiple emotions.

Chapter 6

SUMMARY AND CONCLUSIONS

Intonation is one of the most essential aspects in determining the meaning of a sentence, and it also helps to improve a speaker's intelligibility. The ability to recognise the variations in a phrase relies heavily on normal hearing. Many studies have found that hearing impaired children have trouble distinguishing suprasegmental characteristics, which has a negative impact on suprasegmental perception and production. Traditional and manual methods for intonation training were utilised, but these methods lacked visual feedback, which is critical in hearing-impaired children. Due to the pandemic scenario, patients were unable to attend treatment in person and were forced to switch to tele-practice. This resulted in the creation of a mobile application that serves as a tool for teaching intonation.

There were three stages to the research. Phase 1 comprised of stimulus preparation, phase 2 of application development, and phase 3 of field testing the developed application on CHI. The application was tested on CHI once it was developed to ensure its efficacy. The intonation patterns and pitch contours of both TDC and CHI groups were studied, as the collected data did not follow a normal distribution, non-parametric tests like the Wilcoxon signed ranked test and the Mann-Whitney test were used. Due to the limited sample size and the lower number of therapy sessions. However, there was no significant differences were identified between the two groups in terms of pitch parameters but while analysing the intonation contours it can be noticed that “rise-fall” pattern was seen more in happy and anger emotions and “flat” pattern was seen more in sad emotion in CHI post-therapy. It can also be noticed that the perception and production of different emotions increased in CHI after the intonation training using the developed application.

6.1 Limitations of the present study

- Only 5 TDC and 5 CHI were included in the study.
- There were fewer therapy sessions.

6.2 Implications

- In order to enhance intonation, the developed application may be used in conjunction with normal speech and language therapy.
- The application can be used in real-time across a variety of speech and language disorders in a variety of contexts.
- Tele-practice is much more encouraged during pandemic situations, and these kinds of mobile applications make learning easier and more pleasant for children.
- The created application is one of the first of its kind to be utilized in Kannada language intonation training.

6.3 Future recommendations

The current study sheds insight on the development of an Android application and its usage for intonation training in Children with hearing impairment. The above study can be replicated with large number of participants for better generalisation of results. Further, the developed application can also be incorporated in other Indian languages to cater to the need's persons from different parts of the country. Moreover, the developed application can be utilized for intonation training in a variety of speech and language disorders.

REFERENCES

Agius, J. (2015). Fluency SIS: Smart Intervention Strategy. *Procedia - Social and Behavioral Sciences*, *193*, 7–12. https://doi.org/10.1016/j.sbspro.2015.03.239

Angelocci, A. A., Kopp, G. A., & Holbrook, A. (1964). The Vowel Formants Of Deaf And Normal-Hearing Eleven- To Fourteen-Year-Old Boys. *The Journal of Speech and Hearing Disorders*, *29*, 156–160. https://doi.org/10.1044/jshd.2902.156

Murray, I. R., & Arnott, J. L. (1993). Toward the simulation of emotion in synthetic speech: A review of the literature on human vocal emotion. *The Journal of the Acoustical Society of America*, *93*(2), 1097-1108.

Boothroyd, A., Nickerson, R. S., & Stevens, K. N. (1974). Temporal patterns in the speech of the deaf: an experiment in remedial training.

BRANNON JR, J. B. (1964). *Visual feedback of glossal motions and its influence upon the speech of deaf children*. Northwestern University.

Calvert, 1962. (1962). A PRELIMINARY INVESTIGATION. In *The Tomb of Tut-Ankh-Amen* (pp. 97–109). https://doi.org/10.1017/cbo9780511722349.008

Carney, A. E., & Moeller, M. P. (1998). Treatment efficacy: hearing loss in children. *Journal of Speech, Language, and Hearing Research*, *41*(1), S61-S84.

Crystal, D. (1973). Non-segmental phonology in language acquisition: A review of the issues. *Lingua*, *32*(1-2), 1-45.

Crystal, D. (2012). Prosodic development. *Language Acquisition*, 174–197. https://doi.org/10.1017/cbo9780511620683.011

D'Odorico, L. (1984). Non-segmental features in prelinguistic communications: an analysis of some types of infant cry and non-cry vocalizations. *Journal of child language*, *11*(1), 17-27.

Dworkin, J. P. (1991). Motor speech disorders. *A Treatment Guide*, 85-132.

Friedman, M. (1985). Remediation of intonation contours of hearing-impaired students. *Journal of communication disorders*, *18*(4), 259-272.

Fromkin, V., Rodman, R., & Hyams, N. (2018). *An introduction to language*. Cengage Learning.

Fry, D. B. (1979). *The physics of speech*. Cambridge University Press.

Gonçalves, C., Rocha, T., Reis, A., & Barroso, J. (2017). AppVox: An application to assist people with speech impairments in their speech therapy sessions. *Advances in Intelligent Systems and Computing*, *570*, 581–591. https://doi.org/10.1007/978-3-319-56538-5_59

Green, D. S. (1956). *Fundamental frequency characteristics of the speech of profoundly deaf individuals*. Purdue University.

Hood, R. B., & Dixon, R. F. (1969). Physical characteristics of speech rhythm of deaf and normal-hearing speakers. *Journal of Communication Disorders*, *2*(1), 20-28.

Horii, & 1982. (1982). Some voice fundamental frequency characteristics of oral reading and spontaneous speech by hard-of-hearing young women. *ASHA*, *25*(4), 608–610. https://doi.org/10.1044/jshr.2504.608

Hudgins, C. V, & Numbers, F. C. (1942). An investigation of the intelligibility of the speech of the deaf. *Genetic Psychology Monographs*, *25*, 289–392.

John, J. E. J., & Howarth, J. N. (1965). The Effect of Time Distortions on the Intelligibility of Deaf Children's Speech. *Language and Speech*, *8*(2), 127–134. https://doi.org/10.1177/002383096500800205

Kressin, L., Marquardt, T., Acoustical, C. A.-T. J. of the, & 1976, undefined. (1976). Speech production in two-three-year old children: a perceptual analysis of selected segmental features. *Asa.Scitation.Org*, *59*(S1), 56. https://doi.org/10.1121/1.2002768

Levitt, H., Smith, C. R., & Stromberg, H. (1974). Acoustic, articulatory and perceptual characteristics of the speech of deaf children. *Speech Communication*, *4*, 129-139.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review*, *74*(6), 431–461. https://doi.org/10.1037/H0020279

Luo, X., Fu, Q.-J., & John J. Galvin, I. (2016). Cochlear Implants Special Issue Article: Vocal Emotion Recognition by Normal-Hearing Listeners and Cochlear Implant Users: *Http://Dx.Doi.Org/10.1177/1084713807305301*, *11*(4), 301–315. https://doi.org/10.1177/1084713807305301

Markides, A. (1970). The speech of deaf and partially-hearing children with special reference to factors affecting intelligibility. *International Journal of Language & Communication Disorders*, *5*(2), 126–139. https://doi.org/10.3109/13682827009011511

Mártony, J. (1968). On the correction of the voice pitch level for severely hard of hearing subjects. *American Annals of the Deaf*, 195-202.

McGarr, N. S., & Osberger, M. J. (1978). Pitch deviancy and intelligibility of deaf speech. *Journal of communication Disorders*, *11*(2-3), 237-247.

Menyuk, P. (1972). *The development of speech*. MacMillan Publishing Company.

Metz, D. E., Schiavetti, N., Samar, V. J., & Sitler, R. W. (1990). Acoustic dimensions of hearing-impaired speakers' intelligibility: Segmental and suprasegmental characteristics. *Journal of Speech and Hearing Research*, *33*(3), 476–487. https://doi.org/10.1044/JSHR.3303.476

Minskoff, E. H. (1980). Teaching approach for developing nonverbal communication skills in students with social perception deficits. Part II. Proxemic, vocalic, and artifactual cues. *Journal of Learning Disabilities*, *13*(4), 203–208. https://doi.org/10.1177/002221948001300406

Moncur, J. P., & Brackett, I. P. (1974). *Modifying vocal behavior*. HarperCollins Publishers.

Monsen. (1979). Acoustic qualities of phonation in young hearing-impaired children. *Journal of Speech and Hearing Research*, *22*(2), 270–288. https://doi.org/10.1044/JSHR.2202.270

Monsen, 1978. (1978). Toward measuring how well hearing-impaired children speak. *Journal of Speech and Hearing Research*, *21*(2), 197–219. https://doi.org/10.1044/JSHR.2102.197

Monsen, R. B., & Leiter, E. R. (1975). Comparison of intelligibility with duration and pitch control in the speech of deaf children. *The Journal of the Acoustical Society of America*, *57*(S1), S69–S69. https://doi.org/10.1121/1.1995380

Parkhurst, B. G., & Levitt, H. (1978). The effect of selected prosodic errors on the intelligibility of deaf speech. *Journal of Communication Disorders*, *11*(2-3), 249-256.

Phillips, N. D., Remillard, W., Bass, S., & Pronovost, W. (1968). Teaching of intonation to the deaf by visual pattern matching. *American annals of the deaf*, *113*(2), 239-246.

Pickett, J. M. (1968). Sound patterns of speech: An introductory sketch. *American annals of the deaf*, 120-126.

Rosenhouse, J. (1986). Intonation problems of hearing-impaired hebrew-speaking children. *Language and Speech*, *29*(1), 69–92. https://doi.org/10.1177/002383098602900107

Seidlhofer, B. & Dalton, C., (1994). The significance of pronunciation. *Pronunciation, Oxford University Press, Oxford*, 3-12.

Shenoy, R., Nayak, S., Hegde, M. K., Kini, N., Kundapur, P. P., & Krishnan, G. (2017). Development of an android application in kannada to enhance picture naming skills in persons with aphasia. *2017 International Conference on Advances in Computing, Communications and Informatics, ICACCI 2017*, *2017-Janua*, 2134–2140. https://doi.org/10.1109/ICACCI.2017.8126161

Smith, C., & 1975. (1975). Residual hearing and speech production in deaf children. *ASHA*, *18*(4), 795–811. https://doi.org/10.1044/jshr.1804.795

Stathopoulos, E. T., Duchan, J. F., Sonnenmeier, R. M., & Bruce, N. V. (1986). Intonation and pausing in deaf speech. *Folia Phoniatrica et Logopaedica*, *38*(1), 1–12. https://doi.org/10.1159/000265814

Stevens, K. N., Nickerson, R. S., Boothroyd, A., & Rollins, A. M. (1976). Assessment of nasalization in the speech of deaf children. *Journal of Speech and Hearing Research*, *19*(2), 393–416. https://doi.org/10.1044/jshr.1902.393

Sussman, H., & Hernandez, M. (1979). A spectrographic analysis of the suprasegmental aspects of the speech of hearing-impaired adolescents. *Audiology and Hearing Education*, *5,* 12-16.

Yildirim, S., Bulut, M., Lee, C. M., Kazemzadeh, A., Busso, C., Deng, Z., Lee, S., & Narayanan, S. (2004). An acoustic study of emotions expressed in speech. *8th International Conference on Spoken Language Processing, ICSLP 2004*, 2193–2196. https://doi.org/10.21437/interspeech.2004-242

APPENDIX-I

SL NO.	SENTENCES IN KANNADA	SENTENCES IN IPA	MEANING
1	ಅಮ್ಮ ಟಿ.ವಿ. ಆಫ್ ಮಾಡಬೇಡ	Am'ma ṭivi āph māḍbiḍa	Mom, don't turn off the television.
2	ನಾನು ಐಸ್ ಕ್ರೀಮ್ ಕೊಡಲ್ಲ	Nānu aiskrīm koḍallā	I'm not going to offer you any ice cream.
3	ನಾನು ಸ್ಕೂಲಿಗೆ ಹೋಗಲ್ಲ	Nānu skul hōgalla	I am not going to school.
4	ನನಗೆ ಮೊಬೈಲ್ ಕೊಡು ಆಟಾಡ್ಬೇಕು	Nanagē mobail koḍu āṭāḍbēku	I want to play on my phone, so give it to me.
5	ಟೀಚರ್ ನನಗೆ ಸ್ಟಾರ್ ಕೊಟ್ರು	ˈtiːtʃə Nanagē stɑː koṭru	I got a star from my teacher.
6	ನಾವು ಹೊಸ ಕಾರ್ ತಗೊಂಡ್ವಿ	Nāvu hosa kāru tagoṇḍvi	We bought a new car.
7	ನನ್ನ ಬಾಲ್ ಆ ಹುಡುಗ ತಗೊಂಡ	Nanna bāl ondu huḍuga tagoṇḍa	My ball was taken by the kid.
8	ನಾನು ಕೆಳಗಡೆ ಬಿದ್ದು ಪೆಟ್ಟುಮಾಡಿ ಕೊಂಡೆ	Nānū kelage biddu peṭṭu māḍikoṇḍe	I was injured when I fell.
9	ತಾತಾ ವಾಲ್ಕ್ಗೆ ಕರ್ಕೊಂಡ್ ಹೋಗಿ	Tātā vākke karkoṇḍ hōgi	Grandpa, please take me for a walk.
10	ಅಮ್ಮ ಚಾಕಿಗೆ ದುಡ್ಡು ಕೊಡಿ	Am'ma cākige duḍḍu koḍ	Mom, please give me money so that I may buy chocolate.

APPENDIX-II

CONSENT FORM

DISSERTATION TOPIC: A PRELIMINARY STUDY TO DEVELOP AN ANDROID BASED APPLICATION FOR INTONATION TRAINING IN CHILDREN WITH HEARING IMPAIRMENT

Information to the participants

I, Mr. Jeevan R S, II MSC, studying at AIISH, Mysore is pursuing my dissertation titled

"A preliminary study to develop an android based application for intonation training in Children with Hearing Impairment". This dissertation is done under the guidance of Dr. Reuben Thomas Varghese, Scientist-B, Dept. of Speech-Language Sciences, AIISH, Mysore.

Informed Consent

I have been informed about the aims, objectives, and procedure of the study. I understand that I have a right to refuse participation as a participant or withdraw my consent at any time.

I, ---------------------------------, the undersigned, give my consent to be a participant in this investigation/study.

Signature of the participants
(Name and Address)

Signature of an investigator

Date