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Factors Affecting Speech Intelligibility: A Developmental Study

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Abstract

There is a dearth of research on speech intelligibility in typically developing Tamil speaking children and no published study was reported on the relation between factors such as phonetic accuracy, rate of speech, average amplitude, and frequency range in Tamil speaking children. The aim of this study is to investigate the development of speech intelligibility in typically developing Tamil speaking children in the age range of 2 to 6.11 years. A total of 150 typically developing native tamil speaking children between the age range of 2 and 6.11 years were further divided into 5 groups, with each group consisting of 30 children. Nine sentences in Tamil with increasing complexity was developed to study the developmental trend of speech intelligibility. Each child was seated comfortably and pictures of sentences were randomly presented one after the other as the investigator say the sentence describing the picture. The child was instructed to repeat the sentences after the investigator. Acoustic analysis was done using CSL Model 4500 and frequency range , intensity and rate of speech were calculated.

Perceptual analysis was done using the transcription sheets, by a speech language pathologist. Subsequently, percentage of phoneme correct for words and sentences were calculated, separately. Independent 't' test, pearson's rank correlation, spearman's rank correlation and regression analysis were conducted to find the predictor variables of speech intelligibility. Results revealed, percentage of phoneme correct increased with age and there were no significant gender differences for words and sentences. It was also found that PPC of sentences, intensity average and ROS has a strong positive correlation. As PPC values increases (with age), intensity and rate of speech also increases. Frequency range has no correlation with any of the variables like intensity, PPC and ROS.

Keywords: Speech intelligibility, percentage of phoneme correct, tamil speaking children, intelligibility rating

Introduction

Speech is the oral verbal mode of transmitting messages and involves the precise coordination of oral neuromuscular movements in order to produce sound and linguistic units. The fundamental goal of oral communication is to establish personal and social conduct. the subsystems of speech including respiratory, phonatory, resonatory and articulatory systems, plays an important role to make speech intelligible. Speech intelligibility, in simple words is the speech clarity. (Kennedy, et al, 1996), "speech intelligibility is the accuracy with which a listener is able to decode the acoustic signal of a speaker". For speech to be intelligible, it must have adequate audibility and clarity. The factors affecting speech intelligibility are grouped into 2 different conditions. They are (a) speech characteristics of speaker and,

(b) listener characteristics and conditions. Some of the important speaker parameters that has been studied while measuring the speech intelligibility are, (1) phonetic accuracy, (2) rate of speech, (3) average amplitude, and (4) frequency range.

In a typically developing (TD) child, mastering the production of individual phoneme, suppression of various phonological processes and improvement in speech intelligibility occurs simultaneously. Intelligibility of speech is directly related to the development of articulation and phonological skills, (Bowen, 1998). (Chin, et al., 2002) studied development of speech intelligibility in normal hearing children in the age range of 2 to 6 years, using Beginner's Intelligibility Test (BIT) and concluded that children with normal hearing achieve adult – like speech by 4 years of age or shortly after that. In addition, (Pascoe, 2005) stated that, by 4 years a child's spontaneous speech should be intelligible to unfamiliar adults, even though some articulation and phonological differences are likely to be present. (Flipsen, 2006) devised a formula to obtain the percentage of speech intelligibility with unfamiliar listeners. Percentage of speech intelligibility was thus calculated by dividing child's age in years by 4 and multiplied by 100. In addition to these measures of speech intelligibility, two approaches which are being widely used to determine phonetic accuracy. They are, a) Percentage of Consonants Correct (PCC) (Shriberg, et al., 1982) and b) The Articulation Competence Index (ACI) (Shriberg, 1993). (Kwiatkowski, et al., 1982) showed that Percentage of Consonants Correct (PCC) correlates significantly with clinical ratings of severity. Continuous speech sample is first transcribed. Percentage of consonants correct is then calculated by dividing the correct productions of consonants by total number of consonants and multiplying by 100. Table 1 shows PCC and the corresponding severity level of speech given by (Kwiatkowski, et al., 1982).

Table 1: PCC and Severity of speech intelligibility

PCC Range	Severity
85%	Mild
65-85%	Mild- Moderate
50-65%	Moderate – Severe
<50%	Severe

(Lau Wang Han, 2010) investigated the developmental pattern of phonology in toddlers in Cantonese. Percentage of phoneme correct, percentage of consonant correct, percentage initial consonant correct and percentage final consonant correct was calculated. It was observed that PPC scores differentially diagnosed the speech sound disorder population. It was also stated that all these quantitative measures were suitable to provide an overall impression about phonology.

Another parameter that could influence speech intelligibility is rate of speech (ROS). Rate of speech is number of syllables uttered per minute. It is affected by frequency and duration of hesitation. Speaking rate is determined by the combination of phoneme duration and pauses. (Picheny, et al., 1986) studied the effect of pauses on speech intelligibility and observed that clear speech was highly intelligible when it had reduced speaking rate due to more frequent and longer pauses in conjunction with lengthened speech sounds. In addition, (Sommers, 2006) study indicates that speaking rate important factor of intelligibility. They found that varying speaking rate both naturally and digitally, results in impairment of spoken word identification.

The intrinsic feature of speech is loudness which is been varied according to the situation. Loudness variation in speech is the internal component for speech clarity. Clinically, rating scales are used to evaluate the loudness. Reduced loudness is one of the primary feature in neurological disorder especially,

parkinsons disorder. (Halpern, et al., 2011), investigated the effect of loudness and articulation on speech intelligibility in individuals with Parkinson disease (PD), using Diagnostic Rhyme Test (DRT). Results revealed that speech intelligibility improved when treatment focused on improving loudness, compared to articulation training. This study highlights the importance of loudness training for improving speech intelligibility. A study by (Hazan, et al., 1998) reported the improvement in intelligibility that could be observed by enhancing the amplitude of synthesized speech.

Also, (Bradlow, et al., 1996), studied the relationship between intelligibility scoring and global speaker characteristics, such as, gender, Fo range and speech rate. A multi- talker database containing intelligibility scores for 2000 sentences were studied. Results showed that Fo range is a good predictor of speech intelligibility scores. However, a study by (Markham, et al., 2004) did not show significant correlations between Fo range and word intelligibility.

Need for the study

There is a dearth of research on speech intelligibility in typically developing Tamil speaking children and no published study was reported on the relation between factors such as phonetic accuracy, rate of speech, average amplitude, and frequency range in Tamil speaking children. Children with communication disorders are either under or over identified for speech and language therapeutic services due to lack of normative data on factors affecting speech intelligibility in Tamil during development. Also, developmental normative data will aid in the assessment and pre-post intervention analysis of intelligibility in children with communication disorders.

Given this, and the lack of research in this area, the present study investigated the factors affecting speech intelligibility namely, phonetic accuracy, rate of speech, average amplitude, and frequency range and their relationship in typically developing Tamil speaking children. The aim of this study is to investigate the factors affecting speech intelligibility in typically developing (TD) Tamil speaking children in the age range of 2 to 6.11 years.

Method

Participants: A total of 150 TD native Tamil speaking children between the age range of 2 and 6.11 years participated in the study. These children were further divided into 5 groups. Group I included children in the age range of 2 – 2:11 years; group II were children in the age range of 3 – 3:11 years; group III were children in the age range of 4 – 4:11 years; group IV were children in the age range of 5 – 5:11 years and group V were children in the age range of 6 – 6:11 years. Each group consisted of 30 children. The details of children are given in Table 2.

Table 2: Details of TD children

Groups	Age in years	Boys	Girls
Group I	2 – 2:11	19	11
Group II	3 – 3:11	21	9
Group III	4 – 4:11	17	13
Group IV	5 – 5:11	19	11
Group V	6 – 6:11	17	13

Children were randomly taken from kinder garden and primary classes in four different schools in Chennai. Inclusion criteria for the children to participate in the study are as follows:-

1. Child should pass informal speech, language and hearing screening.

2. He/ She should not have any oro- facial abnormalities.
3. He/ She should not have any neurological deficits.
4. Teachers should report that the child has good learning and academic skills.

Children who did not fit in the inclusion criteria were excluded from the study.

Material: Nine sentences in Tamil with increasing complexity were initially developed for the study. Kinder garden and primary class books were carefully reviewed and language abilities of TD children in the age range of 2 and 7 years were considered while developing the sentences list. The stimuli were simple and picturable and commonly used in everyday life. Thus stimuli consisted of 9 sentences in Tamil. Picture cards were prepared for the sentences. Three pictures were developed for each stimuli by the investigator and was given to 7 judges to rate the appropriateness of the picture with the corresponding sentence. The judges were native Tamil speakers in the age range of 30 to 40 years. Picture that was mostly opted by judges among three options were used in the study.

Procedure: Formal written consent to collect children's speech samples was taken from the school head or principal prior to data collection. Data was collected from each child individually in a quiet room in the school. The child was seated comfortably and pictures of the words and sentences were randomly presented one after the other. The investigator said the sentence or named the word as respective picture was shown, and the child was instructed to repeat the sentences after the investigator. The responses of the children were audio recorded using wavesufer software through laptop. Microphone (i ball distortion free mic, Model No: M27) was placed 10cm from the child's mouth. In case if the child had not listened or understood any stimuli, the investigator repeated it again. Recorded speech samples were then, i) acoustically and ii) perceptually analyzed by the investigator.

a) Acoustic analysis:

Acoustic analysis was done using CSL Model 4500. The recorded samples were loaded into the computer and the variables, rate of speech (syllables / sec), frequency range, and average amplitude were analysed. Rate of speech was calculated as syllables per second. Number of syllables uttered and the duration taken for the utterances by each child during repetition of sentences were calculated, excluding pauses longer than 250ms. Average amplitude was obtained from energy contour analysis option of CSL main program using energy result statistics and frequency range of the utterances of each child was obtained using pitch result statistics option of CSL main program.

b) Perceptual Analysis:

Sentences and words were analyzed perceptually. Recorded samples were presented to a speech language pathologist through headphones in a quiet room. Transcription sheets were provided to transcribe and analyze the samples. Percentages of phoneme correct (PPC) was calculated after indentifying the incorrect phonemes perceptually. Total number of phonemes in the utterance and number of phonemes correctly produced by the children were analyzed and calculated. Transcription sheet for word list and sentences are given in appendix 1 and 2, respectively.

Percentages of phoneme correct for sentences and words were calculated using the formula:-

$$\text{PPC in sentence} = \frac{\text{No. of correct phonemes in sentences} \times 100}{\text{Total no. of phonemes}}$$

Incorrect phonemes in the sentences were analyzed for the presence of phonological processes and their occurrences were calculated and tabulated across each age group.

Overall sentence intelligibility for each child was calculated using – Intelligibility Rating scale developed by **AYJNIHH** (Mani, 1991). It's a 7 point rating scale, in which score "0" indicates 'normal' and "6" indicates 'cannot understand at all even then content I known'.

Statistical Analysis: Statistical package for the social sciences-20 (SPSS) was used for statistical analysis. Mean, standard deviation (SD), and range for variables (PPC, rate of speech, frequency range, and average amplitude) and intelligibility for each group were obtained using case summaries option of SPSS. Independent 't' test was used to find the gender differences within each group across the variables. Overall relation between the variables and intelligibility was obtained using pearson's rank correlation, and relationship within variables for each group was analyzed using spearman's rank correlation. Regression analysis was conducted to find the predictor variables of speech intelligibility.

Results: Results of the study are elaborated under the following subheadings:

a. Phonetic accuracy in sentences
b. Rate of speech (ROS)
c. Average amplitude
d. Frequency range
e. Intelligibility rating
f. Correlation among variables
g. Correlation between variables and intelligibility.

a. Phonetic accuracy in sentences: Percentages of phoneme correct was calculated in sentence task and the findings are as follows.

1) Gender difference: Of 19 boys and 11 girls in group I, only 14 boys and 6 girls could repeat the sentences. Mean PPC for boys and girls are 47.7% and 67.0%, respectively. Independent't' test was conducted to determine the gender difference. Results showed no significant gender difference. Figure 1 shows PPC in sentences in boys and girls across age groups and table 3 shows mean PPC, standard deviation (SD), subject size (n) and number of children who did not respond (no response) and 'p' value, 't' value of independent 't' test.

In group II, of 21 boys and 9 girls, 19 boys and 9 girls could repeat the sentences. Mean PPC for boys and girls are 69.4% and 68.8%, respectively. Independent 't' test showed no significant difference in the performance between genders.

All the children in group III (17 boys and 13 girls) were able to repeat the sentences. Mean percentage of phoneme correct for boys and girls are 89.2% and 91.2%, respectively. Independent 't' test showed no significant difference performance between boys and girls.

Similarly, in group IV, all the children (19 boys and 11 girls) were able to repeat the sentences.

Mean percentage of phoneme correct for boys and girls are 92.5% and 94.3%. Independent 't' test showed no significant difference in performance between genders.

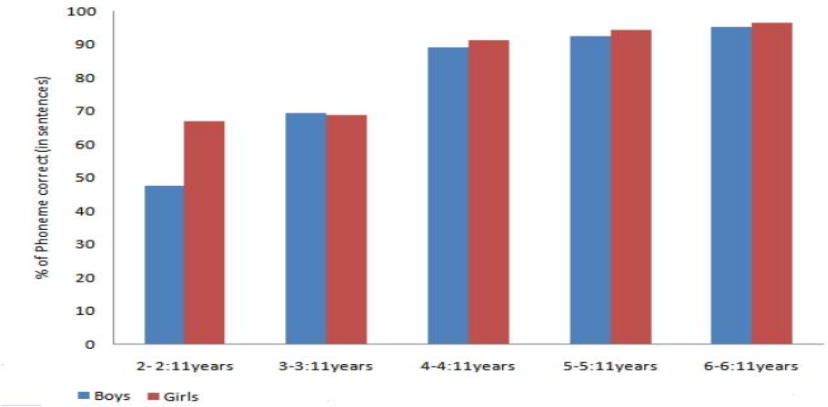
All the children in group V, 17 boys and 13 girls repeated the sentences. Mean percent of -phoneme correct for boys are 95.4% and girls are 96.6%. No significant gender difference was observed in independent 't' test.

Table 3: Mean percentage of PPC, SD, subject size (n), NR (no response) and' p' value and 't' value

Children	2- 2:11 years				3- 3:11 years				4- 4:11 years			5-5:11 years			6- 6:11 years		
	N	NR	Mean %	SD	N	NR	Mean	SD	N	Mean %	SD	N	Mean %	SD	N	Mean %	SD
Boys	19	5	47.7	26.7	21	1	69.4	15.6	17	89.2	7.4	19	92.5	2.4	17	95.4	2.6
Girls	11	5	67.0	13.9	9	-	68.8	18.1	13	91.2	4.0	11	94.3	3.3	13	96.6	1.8
Total	30	10	53.5	24.9	30	1	69.2	16.1	30	91.1	6.2	30	93.2	2.9	30	95.9	2.3
'p'value	.069				.636				.143			.409			.281		
't'value	.115				.939				.407			.106			.198		

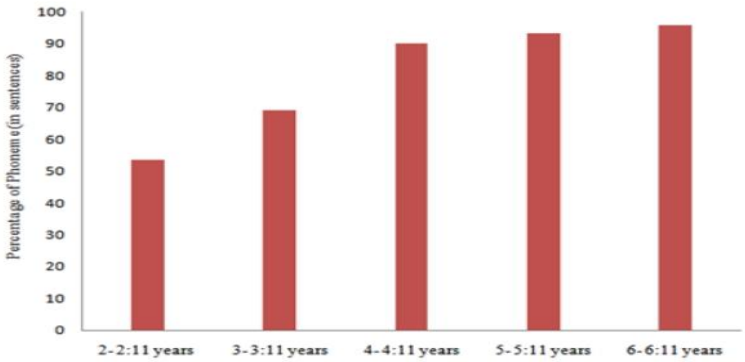
of independent 't' test in phonetic accuracy in sentence task.

Figure 1: Percentages of phoneme correct in sentence in boy and girls across age groups.



2) **Group difference**: Mean values of PPC in sentences increased with age. Mean values of PPC of group I is 53.5%, group II is 69.2%, group III is 91.1%, group IV is 93.2% and group V is 95.9%. Figure 2 shows the mean values of PPC in sentences across age.

Figure 2: Percentages of phoneme correct in sentence across age groups.



b. Rate of speech (ROS): Rate of speech is assessed using sentence task. It is calculated in number of syllables per second.

1) Gender difference:

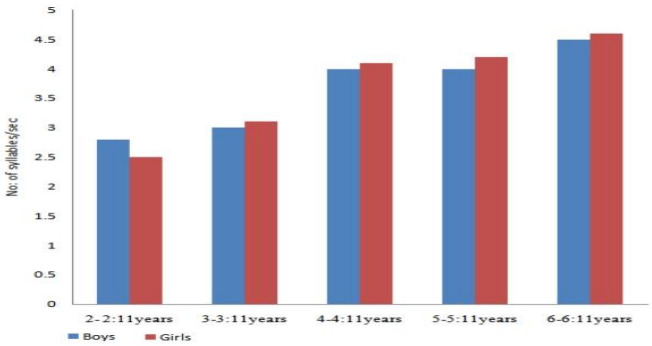
Of 19 boys and 11 girls in group I, only 14 boys and 6 girls could repeat the sentences. Mean ROS for boys and girls are 2.8 syllables/second and 2.5 syllables/second, respectively. Figure 3 shows mean ROS in boys and girls across age groups and table 4 shows mean ROS, standard deviation (SD), subject size (n), number of children who did not respond (no response) and 'p' value and 't' value of independent 't' test.

In group II, of 21 boys and 9 girls, 19 boys and 9 girls could repeat the sentences. The mean ROS for boys and girls are 3.0 syllables /sec and 3.1 syllables / second, respectively. All the children in group III (17 boys and 13 girls), were able to repeat the sentences. The mean ROS for boys and girls are, 4.0 syllables /sec and 4.1 syllables /sec, respectively. In group IV (5- 5:11 years) also, all children participated (19 boys and 11 girls) were able to repeat the sentences. The mean ROS for boys and girls are 4.0 syllables /sec and 4.2 syllables /sec, respectively. All the children in group V, 17 boys and 13 girls repeated the sentences. Mean ROS for boys and girls are 4.5 syllables /sec and 4.6 syllables /sec, respectively. Boys and girls of all age groups showed no significance except Group I (2- 2:11 years) in 'Independent t test'.

Table 4: Mean, SD, n, NR (no response) and 'p'value and 't'value of independent 't' test of rate of speech

Children	**2- 2:11 years**				**3- 3:11 years**				**4- 4:11 years**			**5-5:11 years**			**6- 6:11 years**		
	N	NR	Mean %	SD	N	NR	Mean	SD	N	Mean %	SD	N	Mean %	SD	N	Mean %	SD
Boys	19	5	2.8	.5	21	1	3.0	.6	17	4.0	.63	19	4.0	.73	17	4.5	.45
Girls	11	5	2.5	.6	9	0	3.1	.5	13	4.1	.34	11	4.2	.38	13	4.6	.5
Total	30	10	2.5		30	1	3.0		30	4.1	0.5	30	4.1		30	4.5	
'p'value	.007				.312				.153			.259			.728		
't'value	.466				.886				.583			.332			.578		

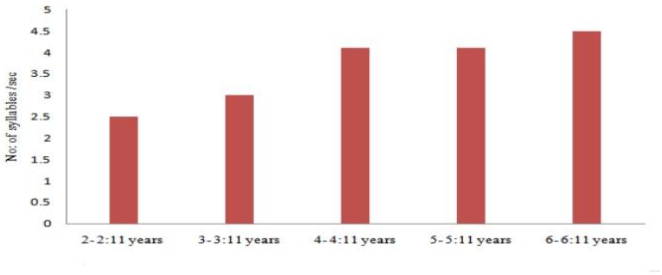
Figure 3: Rate of speech compared between boys and girls in different age groups



2) **Group difference**:

Mean values of ROS in sentences increased with age. Mean values of ROS of group I is 2.5 syllables/sec, group II is 3.0 syllables/sec, group III is 4.1 syllables/sec, group IV is 4.1 syllables/sec and group V is 4.5 syllables/sec. Figure 4 shows the mean values of ROS across age.

Figure 4: Rate of Speech of children across age groups



d. Average amplitude (Io)

1) Gender difference:

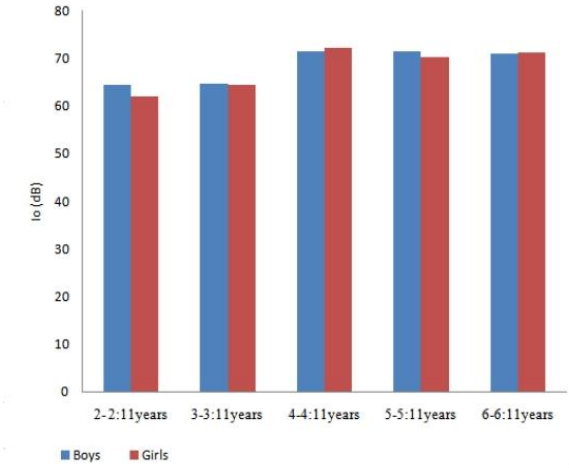
Mean Io for boys and girls in group I are 64.4dB and 62.0 dB, respectively. Table 5 shows mean Io, standard deviation (SD), number of participants (n), number of children who did not respond (no response) and 'p'value, 't'value of independent 't' test. Figure 5 shows mean Io in boys and girls across age groups

In group II, of 21 boys and 9 girls, 19 boys and 9 girls could repeat the sentences. The mean Io for boys and girls are 64.7dB and 64.5dB, respectively. All the children in group III (17 boys and 13 girls), were able to repeat the sentences. The mean Io for boys and girls are, 71.4dB and 72.2dB, respectively. In group IV (5- 5:11 years) also, all children participated (19 boys and 11 girls) were able to repeat the sentences. The mean Io for boys and girls are 71.4dB and 70.2 dB, respectively. All the children in group V, 17 boys and 13 girls repeated the sentences. The mean Io for boys & girls are 71.0 & 71.1 (dB), respectively. Independent t test did not reveal gender differences ($p>0.05$) within group I, II, III, IV and V.

Table 5: Mean, SD, n, NR (no response) and 'p'value and 't'value of independent 't' test of average amplitude

Children	**2- 2:11 years**				**3- 3:11 years**				**4- 4:11 years**			**5-5:11 years**			**6- 6:11 years**		
	N	NR	Mean %	SD	N	NR	Mean	SD	N	Mean %	SD	N	Mean %	SD	N	Mean %	SD
Boys	19	5	64.4	2.6	21	1	64.7	6.1	17	71.4	4.7	19	71.4	3.9	17	71.0	4.5
Girls	11	5	62.0	3.0	9	0	64.5	6.7	13	72.2	4.0	11	70.2	3.8	13	71.1	3.7
Total	30	10	63.7	2.9	30	1	64.7	6.2	30	71.7	4.4	30	71.0	3.8	30	71.0	4.1
'p'value	.122				.782				.477			.703			.413		
't'value	.221				.933				.612			.445			.958		

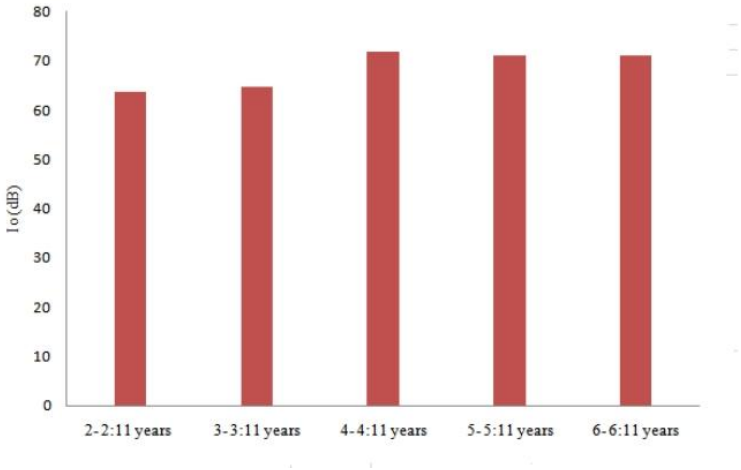
Figure 5: Mean intensity in boys and girls across age groups



2) Group difference:

Mean values of intensity in sentences increased with age. Mean values of intensity of group I is 63.7 dB, group II is 64.7 dB, group III is 71.7 dB, group IV is 71.0 dB and group V is 71.0dB. Figure 6 shows the mean values of intensity across age.

Figure 6: Mean intensity (dB) across groups



d. Frequency range

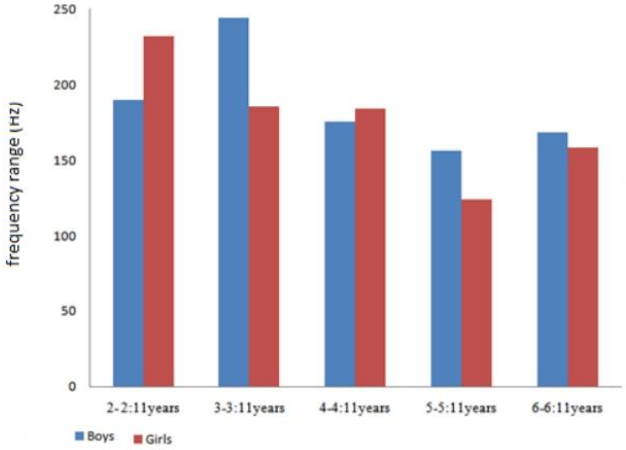
1) Gender difference:

Mean frequency ranges for boys and girls are 189.9 Hz and 232.2 Hz, respectively. Table 6 shows details of mean frequency range, standard deviation (SD), subject size (n), number of children who did not respond (no response) and 'p'value, 't'value of independent 't'test. Figure 7 shows the mean frequency range in boys and girls across age groups. In group II, of 21 boys and 9 girls, 19 boys and 9 girls could repeat the sentences. The mean frequency range of boys and girls are 243.9 Hz and 185.6 Hz, respectively. All the children in group III (17 boys and 13 girls), were able to repeat the sentences. The mean frequency range for boys and girls are, 175.1 Hz and 184.1 Hz, respectively. In group IV, mean frequency range for boys is 156.3Hz and girls is 124 Hz. Mean frequency range for boys and girls in group V are 168.0Hz and 158.2Hz, respectively. Independent't' test revealed significant gender differences in mean frequency range only for Group II (children of 3- 3:11 years).

Table 6:Mean, SD, subject size (n), NR (no response), 'p'value and 't'value of independent't' test of frequency range.

Children	2- 2:11 years				3- 3:11 years				4- 4:11 years			5-5:11 years			6- 6:11 years		
	N	NR	Mean%	SD	N	NR	Mean	SD	N	Mean%	SD	N	Mean%	SD	N	Mean%	SD
Boys	19	5	189.9	62.7	21	1	243.9	101.0	17	175.1	86.0	19	156.3	83.4	17	168.0	66.5
Girls	11	5	232.2	126.8	9	0	185.6	72.4	13	184.1	69.2	11	124.0	80.3	13	158.2	97.0
Total	30	10	202.6	85.5	30	1	225.8	95.8	30	179.0	78.0	30	144.4	82.4	30	163.8	79.7
'p'value	.478				.057				.987			.756			.629		
't'value	.085				.093				.315			.040			.024		

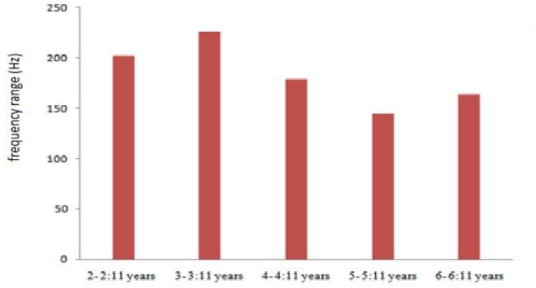
Figure 7: Frequency range (Hz) of boys and girls across Gender



2) Group difference:

Mean values of frequency range in sentences of group I is 202.6Hz, group II is 225.8Hz, group III is 179.0Hz, group IV is 144.4Hz and group V is 163.8Hz. Figure 8 shows the mean values of frequency range across age.

Figure 8: Frequency range (Hz) across Group



e. Speech Intelligibility Rating

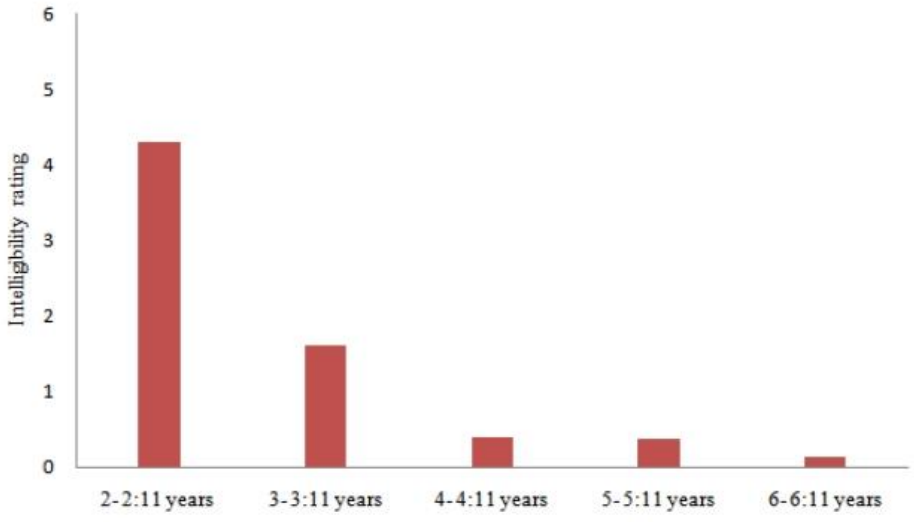
1) Group difference:

Mean values of Intelligibility rating in sentences increased with age. AYJNIHH rating scale is a 7 point scale where score '0' indicate 'normal speech' and '6' indicate 'unintelligible speech'. Mean values of intelligibility of group I is 4.2, group II is 1.7, group III is 0.43, group IV is 0.36and group V is 0.13. Figure 9 shows the mean values of intelligibility across age. Table 7 shows the mean and SD of overall intelligibility across groups.

Table 7: Mean & SD of overall intelligibility across groups.

Age groups	Mean scores	SD
2- 2:11 years	4.3	1.4
3- 3:11 years	1.6	1.0
4- 4:11 years	0.4	0.6
5- 5:11 years	0.36	0.55
6- 6:11 years	0.13	0.34

Figure 9: Intelligibility rating of AYJNIHH across Group



Note: score '0' indicate 'normal speech' and '6' indicate 'unintelligible speech'

f. Correlation among variables:

Pearson correlation was conducted to determine the correlation between variables across all age groups. Variable PPC has strong positive correlation with intensity ($r(137)=.442$, $p<0.05$) and rate of speech ($r(137)= .593$, $p<0.05$). As PPC values increases (with age) average amplitude and rate of speech also increases. PPC also have a strong negative correlation with frequency range($r(137)= -.242$, $p>0.05$). ROS and intensity show a strong positive correlation. Frequency range has no correlation with average amplitude and has negative correlation with PPC and ROS. Table 8 shows the results of correlation matrix among variables.

Table 8: Correlation matrix among variables

	PPC sentences	ROS	Intensity	F range
PPC sentences	-	.593	.442*	.242**

ROS	.593	-	.484**	-.231**
Intensity	.442**	.484**		-.082
F Range	.242**	-.231**	-.082	-

*p<.05; **p<.01

g. Correlation between variables and unintelligibility:

Spearman rank correlation was used to find the correlation between variables and unintelligibility. It was found that unintelligibile speech has a strong negative correlation with PPC, ROS and average amplitude and no correlation with frequency range. As speech intelligibility decreases PPC, ROS and intensity also reduced. As speech intelligibility increases PPC, ROS and intensity also increases. Table 9 shows the results of correlation matrix between unintelligibility and variables.

Table 9: Correlation matrix between variables and unintelligibility.

	PPC sentence	Average amplitude	ROS	F range
Correlation coefficient for unintelligible speech	-.719**	-.488**	-.654**	.166

*p<.05; **p<.01

Stepwise multiple regression analysis was conducted to determine the predictor variables of speech intelligibility. Table 10 shows the results of regression analysis.

Table 10: Regression analysis results for Intelligibility variables

Variable	R square change	p value
PPC	.49	.000**
ROS	.09	.000**
Average amplitude	.02	.000**

**pvalue<.01

Three variables predicted intelligibility of Tamil speaking typically developing children. They are, a) PPC of sentence, b) Rate of speech, c) Intensity average. Percentage of Phoneme correct of sentence accounts for 49% of variance (p= .000), ROS accounts for 9% of variance (p= .000) and average amplitude accounts 2% of variance (p=.000). Total prediction measures accounted for 60% of variance of the criterion variable of speaker intelligibility.

Discussion

Results revealed many interesting findings. First, Percentage of Phoneme Correct (PPC) in sentences and words increased with age. Within groups, there was no significant gender difference for sentences. Mean values of PPC in sentences of group I is 53.5%, group II is 69.2%, group III is 91.1%, group IV is 93.2% and group V is 95.9%. From these results it can be suggested that TD Tamil speaking children acquire 50 % of PPC understandable to even unfamiliar listeners by 2 – 2:11 years of age and by 4-4.11 years children were >90% of PPC. (Chin, et al., 2002) found similar results in English speaking children of 2 years (53.9% of word correct). In consonance with the findings of the current study, (Coplan, et al., 1988); (Chin, et al., 2002); (Pascoe, 2005); (Flip-sen, 2006), reported

that by 4 years of age children achieve speech intelligibility that is understandable to all listeners. Increase in PPC scores with age may be due to acquisition of new phonemes with age. (Shakeela, et al., 2013) reported that Srilankan Tamil speaking children achieve 75% of speech sounds by 4 years of age and also stated that age has a significant influence on phoneme acquisition and on the suppression of phonological error patterns. Also, (Sander, et al., 1972) found that English speaking children acquired new phonemes as age increases.

Second, rate of speech (no: of syllables/ sec) increased with age, and significant gender difference was observed only for children of 2- 2:11 years. Rate of speech was 2.5 syllables/ sec for 2- 2:11 years; 3.0 syllables/ sec for 3- 3:11 years; 4.1 syllables/ sec for 4- 4:11 years; 4.1 syllables/ sec for 5- 5:11 years and 4.5 syllables/ sec for 6- 6:11 years. (Savithri, et al., 2006) reported that by 4 years of age Tamil speaking children produce 6 syllables/ second in descriptive task. This variation in findings may be due to the difference in the task used. In the current study repetition task was used. (Sturm, et al., 2007) found that ROS increased with increase in age between 7 to 9 years and leveled off between 9 to 11 years but the present study observed that ROS increased with increase in age up to 4 years and, it stabilized between 4:11 to 6:11years of age. This variation in the findings could be due to difference in the methodology as the current study used repetition task, whereas (Sturm, et al., 2007) used narrative and conversational task. Also, in the current study the age range investigated was 2 to 6.11 years. It will be interesting to study the older (7 to 12 years) Tamil speaking children to know if the there is any change in the trend in ROS. Significant gender difference in ROS in 2-2.11 years old children may be due to the difference in the number of girls (6) and boys (14) who could repeat the sentences.

Third, average amplitude increases with age and there was no significant difference between boys and girls in each group. Similar to the findings of ROS, amplitude average also increased up to 4 years of age and then it was observed that this development leveled off between 4:11 years to 6:11 years. Mean scores of amplitude average for 2- 2:11years was 63.7 dB; 64.7 dB for 3- 3:11 years; 71.7dB for 4- 4:11 years; 71.0 dB for 5- 5:11 years and the older group 6- 6:11 years had 71.0 dB. Till date, no published researches on the developmental changes of amplitude were reported.

Fourth, frequency range in sentences of children in 2- 2:11 years is 202.6Hz, 3- 3;11 years is 225.8Hz, 179.0Hz for children of 4- 4:11 years, 144.4Hz for 5- 5:11 years and older group children had 163.8Hz. Frequency range was significantly different in boys (243.9 Hz) and girls (185.6 Hz) only for children of 3- 3:11 years. The reason for this finding is not known. It may be because of difference in the subject size (boys: 19 and girls:11). It was observed that those children in 2- 2:11years had wider frequency range compared to 6- 6:11 year old children. No research has been reported on the developmental trend of frequency range in children.

Fifth, mean values of Intelligibility rating in sentences increased with age. Score ‘0’ indicate ‘normal speech’ and ‘6’ indicate ‘unintelligible speech’. Mean values of intelligibility of children of 2- 2:11 years is 4.2, 3- 3:11 years is 1.7, 4- 4:11 years is 0.43, 5- 5:11 years is 0.36 and the older group children of 6:6:11 years is 0.13. In consonance with the findings of the current study, (Chin, et al., 2002) has reported that for English speaking children of 2 to 6 years speech intelligibility improved with age. Also, (Lynch, et al., 1980); (Weiss, 1982); (Bowen, 1988); (Flipsen, 2006) has suggested that percentage of speech intelligibility increases with increase in age.

Sixth, it was found that PPC of sentences, intensity average and ROS has a strong positive correlation. As PPC values increases (with age), intensity and rate of speech also increases. Frequency range has no correlation with any of the variables like intensity, PPC and ROS.

Seventh, unintelligible speech showed strong negative correlation with PPC, ROS and average amplitude. This means that with increase in speech intelligibility, PPC, ROS and average amplitude also increases. Regression analysis predicted that PPC accounts for 49% of variance for overall intelligibility rating. (Masterson, et al., 1991) reported PPC measure determines the overall speech intelligibility. Also, (Hodge, et al., 2012) found strong correlation between PPC and overall intelligibility rating for both word and sentence task.

Speech intelligibility increased with increase in rate of speech. It was found that ROS accounts for 9% of variance for overall speech intelligibility. (Sommers et al., 2006) also found that ROS is an important factor to determine the speech intelligibility. In addition, (Prezas, 2008) studied that ROS accounts for 10% of variance for intelligibility rating in Spanish language. Another variable, amplitude average had a strong negative correlation with unintelligibility. It was also found that amplitude average accounts 2% of variance for intelligibility rating. In consonance, (Halpern, et al., 2011) and (Soloman, et al., 2001) reported that loudness training using LSVT in individual with Parkinson disease helps in improving the speech intelligibility. Also, (Hazan, et al., 1988) reported the improvement in speech intelligibility by enhancing the amplitude of synthesized speech. Frequency range has no correlation with intelligibility. In congruence to these results, (Hazan, et al., 2004) suggested that there is no correlation between frequency range and word intelligibility.

Conclusion

The current investigation yielded important findings related to speech intelligibility. Present study recommends that to use the normative obtained for the variables, phonetic accuracy, ROS and amplitude average in children in children between 2 to 6:11 years to analyze the speech intelligibility of children with communication disorders of the same age groups. These sentences, words and pictures developed in the study will be a useful tool in the assessment of children.

Current study considered only four variables (phonetic accuracy, rate of speech, amplitude average and frequency range) and studied their influence on speech intelligibility in TD children. Further research to study the relationship of factors such as vowel space, prosody, phoneme duration, pause frequency, pause duration, formant frequency, formant bandwidth, spectral balance and intelligibility is required in TD children in Tamil and other languages. The speech samples in the present study were judged by one listener. Future studies can consider using more listeners to rate speech samples and their inter judge reliability can be obtained. Repetition task was used to study the factors of speech intelligibility. It is recommended to use spontaneous speech/ descriptive task to evaluate the factors of speech intelligibility. The study can also be replicated in other dialects of Tamil to analyze the factors related to dialectal differences in speech intelligibility.

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