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Manasagangothri, Mysore - 570 006

Phone: 0821-2514449, 2515218, 2515905, Fax: 0821-2510515

Website: www.aiishmysore.in, e-mail: director@aiishmysore.in

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Editorial

Greetings from AIISH, Mysore!

The Journal of All India Institute of Speech and Hearing (JAIISH), Vol. 31 consists of 28 articles in the areas of speech, language and hearing. E-format of the Journal is also accessible in the portal http://aiish.ac.in directly or through AIISH website aiishmysore.com.

Speech acoustics and studies on various clinical population such as Sub-Mucous Cleft, Dysarthria, Laryngeal Aerodynamic and Babbling are covered under Speech. Adaptation of tests, effect of Bilingualism, Manuals, SLI, Lexical Processing, Reaction time, Comprehension in persons with Aphasia, Perception of fast and time compressed speech, Telepractice, relationship between Auditory perception and reading, Visual perception and reading are covered under Language.

The articles under Hearing include review about Myogenic potential, Cochlear Hydrops, Disability access audit, effect of noise on Biomark in persons with learning disability, Physiological basis of encoding of speech evoked FFR and Hearing aid processed speech.

All the articles have been subjected to plagiarism check. I thank the Editorial Board for thoroughly reviewing and editing articles and I hope that it will be useful for community of speech and Hearing. Comments on the articles may be sent to Dr. S.R. Savithri, Editorial Chief at the email: director@aiishmysore.in

Dr. S. R. Savithri
Director & Chief Editor

COMPARISON OF NASALANCE VALUES OBTAINED FROM NASALITY VISUALIZATION SYSTEM AND NASOMETER II

[1]Madhu Sudarshan Reddy B., [2]Sheela S. & [3]Gopi Kishore Pebbili

Abstract

This study was designed to compare nasalance scores obtained with the Nasality visualization system (NVS) and Nasometer II (NM), and to evaluate test-retest reliability of nasalance scores on each of these instruments. Twenty two adult females, without any resonance or articulation disorders, in the age range of 17 to 25 years were considered for the study. Nasalance values were obtained using NVS and NM for the stimuli vowels (/a/, i// and /u/), syllables (/pa/, /ta/, /ka/, /ba/, /da/ and /ga/), eight oral and eight nasal sentences. Following familiarization task, the participants were instructed to read the stimuli with the headset/separator handle for the actual recording. Results indicated trends of increase in nasalance values with increase in vowel height, place of articulation moving backward in the oral tract, and voicing. Paired sample t test revealed significant difference between the nasalance measured by NVS and NM instruments across all the stimuli at $p < 0.05$ level of significance. Chronbach's alpha revealed good test retest reliability for both NVS and NM for most of the stimuli ($\alpha > 0.70$). From the findings of the study it may be concluded that nasalance values obtained from the Nasometer II and Nasal visualization system are not interchangeable and cannot be compared directly. The normative data, cutoff scores, sensitivity, specificity and other data of NM might not be applicable to nasalance values obtained from NVS and therefore, has to be established separately for NVS. Good test retest reliability obtained in the present study for NVS makes it a reliable nasalance measuring tool for clinical and research purposes. However, further studies investigating diagnostic efficacy using clinical population and correlations of perceptual analysis of nasalance might verify the validity of this instrument.

Keywords: *Nasalence, Velopharyngeal dysfunction*

Normal speech production depends, in part, on the ability to rapidly couple and decouple the nasal cavity from the oral cavity. Nasal speech sounds require oral nasal coupling, oral sounds require oral nasal decoupling. The process of coupling and decoupling the oral and nasal cavities for speech is called velopharyngeal valving. This valving is controlled by elevation of the velum and constriction of the pharyngeal walls. However, persons with structural anomalies such as cleft palate and with neuromuscular disorders such as dysarthria face difficulty in maintaining adequate velopharyngeal valving, also known as velopharyngeal dysfunction. Velopharyngeal dysfunction or presence of passages between oral and nasal chambers such as caused by cleft may result in excessive nasal resonance in the speech (hypernasality). Hyponasality is another condition characterized by reduced nasal resonance in speech. It may result from the conditions such as blocked nose associated with nasal congestion due to common cold or due to anatomical condition such as deviation of nasal septum. It is essential to have sensitive tools to assess these individuals with deviant nasality and to make appropriate treatment decisions. Nasalance is the proportion of nasal energy to the total acoustic energy in a speech signal. It allows the speech-language pathologist to substantiate the perceptual assessment and to provide a quantitative measure of perceived nasality. Nasalance measure acts as a supplement for the speech evaluation of individuals with resonance disorders resulting from cleft palate and other craniofacial disorders.

Spectrography has been applied extensively by a number of researchers (Curtis, 1942; Hattori et al., 1958; Fant, 1960; and Dickson, 1962) in studies designed to specify the acoustic characteristics of hypernasality. Oral-nasal sound pressure levels (SPL) have been studied by several researchers seeking correlates of perceived hypernasality. This technique uses microphones to record oral and nasal sound pressure levels. Weiss (1954) employed probe microphones to measure oral and nasal SPLs during speech. The first instrument to measure oral and nasal acoustic energy was first developed by Samuel Fletcher in 1970. This instrument is called TONAR, which is an acronym for Oral Nasal acoustic ratio (Fletcher

[1]Student, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: madhusudarshan@rocketmail.com, [2]Research officer, AIISH, Mysore-06, Email: sheela.mslp@gmail.com & [3]Lecturer in Speech Pathology, AIISH, Mysore-06, Email: gopiaslp@gmail.com

& Bishop 1970). The TONAR was later updated, revised and then renamed as TONAR II (Fletcher, 1976a, 1976b). Since its introduction, numerous investigations have been conducted to evaluate the validity and reliability of nasalance scores (e.g., Fletcher and Bishop, 1970; Fletcher, 1978; Dalston et al., 1991; Dalston and Seaver, 1992; Hardin et al., 1992; Karnell, 1995; Watterson et al., 1998, 1999; Lewis et al., 2000).

The TONAR did not employ acoustic filtering, however it was modified to include filtering based on the data from Fletcher and Bishop (1970); Fletcher, (1978), which suggested that filtering optimizes agreement between listener judgments of nasality and nasalance scores.

The Nasometer 6200 (Kay Elemetrics Corp., Lincoln Park, NJ) was developed by Fletcher, Adams, McCutcheon in 1987, and it is commonly used in the assessment of hypernasal speech (e.g., Kummer, 2001). It was a development of the TONAR II (S G Fletcher, Adams, & McCutcheon, 1989). The Nasometer 6200 comprises a headset with a sound-separator plate and two microphones. An analog preamplifier filters the signal with a bandwidth of 300 Hz around a 500 Hz center frequency. The filtered signal is then converted to DC voltage and fed to the application software for further analysis.

Nasometer II, Model 6450 (Kay Pentax), is the newest hardware/software version of the Nasometer 6200 developed in the year 2002. Although the Nasometer II is similar to the old Nasometer, it is also different in ways that may introduce variability in nasalance scores between the new machine and its predecessor. First, the new Nasometer II is a hybrid that uses both digital and analog circuitry, whereas the old Nasometer uses only analog circuitry. In both Nasometers, the oral and nasal acoustic waveforms are filtered as analog signals with a 300 Hz band-pass filter having a center frequency of 500 Hz. However, the Nasometer II converts the analog signals to digital signals after filtering, but before computing, the nasalance score. Second, the old Nasometer reports nasalance scores to the second decimal place, whereas the Nasometer II reports nasalance scores rounded to the nearest whole number.

The Oro Nasal system (Glottal Enterprises Inc., Syracuse, NY) is another instrument developed for the measurement of nasality. It uses a handheld circumvented facial mask with a soft sound-separation plate that is held against the patient's face. Two microphones positioned in the separate nasal and oral compartments of the mask record the patient's speech. These microphones are mounted inside the handle case, which also contains the preamplifier. The microphones are located at the end of two plastic tubes (about 1 cm in length and 2 mm in diameter) that hold the soft facial mask in place. Software and handling of the OroNasal system are comparable to those of the Nasometer and the Nasal View. Recordings are made in 16-bit quality with a sampling rate that can be set to either 11.25 or 22.5 kHz.

Glottal Enterprises Inc., (Syracuse, NY) in 2005 introduced Nasality Visualization System (NVS) which is an advanced version of the Oro Nasal system. It provides the nasalance measurement through Nasalance System (NAS) and Nasal air emission measurement through the Nasal Emission System (NEM). The instrument uses Rothenberg's dual-chamber circumvented airflow mask for recording and analyzing nasalance and nasal air emissions. NVS provides many user-friendly features such as USB operation, color-differentiated display that clearly separates vowels, unvoiced consonants and nasal consonants. *It has an additional feature to eliminate* nasal consonants from the average-nasalance computation. Further, this instrument uses a separator handle rather than head straps for the *measurement of nasalance.*

Orienting nasalance values for the Nasometer have been established for speaker groups of variable sizes and compositions for North American English (Seaver et al., 1991), Spanish-speaking females (Anderson, 1996), Australian English (Van Doorn and Purcell, 1998), Mid-West Japanese (Tachimura et al., 2000), German (Mu¨ller et al. 2000), Cantonese-speaking females (Whitehill, 2001), and young Flemish adults (Van Lierde et al., 2001). In a preliminary study by Awan (1998) with a total of 181 normal participants, measurements obtained with the Nasal View differed from measurements made with the Nasometer. Mean nasalance scores measured with the Nasal View were higher for non-nasal stimuli and lower for nasal stimuli in comparison to the Nasometer. Awan (1998) attributed this finding to the fact that the signal in the Nasal View is not band pass filtered, as it is in the Nasometer. The mean differences between repeated measurements were within a 2% to 3% range of nasalance for both instruments. However, Awan did not report whether the observed differences in nasalance magnitude as obtained with the Nasometer and the Nasal View were statistically significant. It should also be noted that Awan (1998) used a prototype version of the NasalView that was only capable of 8-bit s ignal encoding, as opposed to the current 16-bit version.

Lewis and Watterson (2003) compared nasalance scores from the Nasometer and the current Nasal View with 16-bit resolution for five test sentences that were loaded with different vowels (Lewis et al., 2000). The authors concluded that nasalance scores from the NasalView are qualitatively and quantitatively different from those of the Nasometer. The study by Bressmann (2005) has compared nasalance scores in normal participants for three systems Nasometer, the Nasal View, and the Oro Nasal System. Results indicated that Nasometer had the lowest nasalance scores for the non-nasal Zoo Passage. The Nasal View had the highest nasalance scores for the phonetically balanced Rainbow Passage. The OroNasal System had the lowest nasalance scores for the Nasal Sentences.

Subject test-retest variability has been evaluated previously in several studies using the old Nasometer (Seaver et al., 1991; Litzaw and Dalston, 1992; Kavanagh et al., 1994; Mayo et al., 1996; Van Doorn and Purcell, 1998). Seaver et al. (1991) evaluated test-retest variability in 40 subjects with normal speech by asking each subject to read each of three passages, three times in succession. The three passages were the Zoo Passage, the Rainbow Passage, and the Nasal Sentences. Cumulative frequency distributions showed that 97% of the nasalance scores for any single reading of the Zoo Passage were within three nasalance points of any other reading of that passage. For the Rainbow Passage, 91% were within three nasalance points, and for the Nasal Sentences, 94% were within three nasalance points. These data indicate minimal within-subject performance variability. Kavanagh et al. (1994) evaluated test-retest variability in nasalance scores after removing and replacing the Nasometer headgear. In this study, 52 adults with normal speech were asked to read each of the three standard passages three times, but between the second and third reading, the headgear was removed and replaced. Analysis of variance (ANOVA) showed no significant difference between any readings of the Zoo Passage or the Rainbow Passage, but there was a significant difference between the first and third readings of the Nasal Sentences. Cumulative frequency data were not reported.

To summarize, the instrumental means for assessing hypernasality and other resonance disorders have been gradually evolving and are gaining in popularity. As the evolution progress towards the replacement of old machines or invention of new machines, it will be critical for clinical purposes to find out normative data or to know exactly how the two machines compare. Can a clinician obtain a nasalance score from Nasality visualization system and compare it in a meaningful way with Nasometer II nasalance score? The answer to such questions will remain uncertain until the two machines are compared. According to Bressmann (2005) "The Nasometer is currently the most commonly used instrument for nasalance analysis and has been used for diagnosis and research with a wide variety of different languages and disorders" (p. 425).

However, the Nasality visualization system may be an affordable alternate for clinicians and institutions with added advantages of user friendliness. Hence, it is essential to investigate whether these two instruments provide comparable results. Further, since the Nasality visualization system being the newly introduced system, there is no normative or clinical data available. The present study was taken up to answer the research questions (1) does nasalance scores obtained from the Nasality visualization system are comparable to those obtained from the Nasometer II (2) does the obtained difference, if any, be statistically or clinically significant, and (3) whether the two instruments provide similar test-retest reliability?

Aim of the study

The aim of the study was to obtain nasalance values obtained from Nasality visualization system and Nasometer instruments for Vowels, voiced and unvoiced stop consonants in various place of articulation in the context of vowel /a/, sentences (oral and nasal) and to compare the nasalence across the above stimuli; and to establish the test-retest reliability of the measures obtained from Nasality visualization system and Nasometer.

Method

Participants

Twenty two adult females in the age range of 17 to 25 years were considered for the study. All the participants were native speakers of Kannada language. All the participants had reported no history of structural and functional abnormality of the oral mechanism or nasal obstruction or hearing problem. It was ensured that the participants were not suffering from common cold or any other upper respiratory tract infections on the day of testing.

Instrumentation

Nasometer (model 6400 II, Kay Pentax, New Jersey) and Nasal visualization system (Glottal Enterprises) was used to obtain nasalance scores. Nasometer II was calibrated each day prior to the data collection based on the guidelines provided by the manufacturer. Although there is no such calibration function for Nasality visualization system, the input connection and recording level was checked for separator handle based on manufacturer's guidelines. This was performed each day prior to the data collection.

Material

Stimuli in Kannada language consisting of vowels, syllables (CV) and sentences were considered for the study. Vowels /a/, /i/, /u/; syllables with /p/, /t/, /k/, /b/, /d/, /g/ phonemes in the contexts of /a/,/i/,/u/ and sentences including eight oral sentences, eight nasal sentences were considered. Each participant was made to produce a total of 37 stimuli (3vowels x 18 syllables x 16 sentences).

Recording Procedures

All the recordings were made in the quiet chamber, with the participants seated in a comfortable chair. The recordings were obtained from the two instruments on three separate days. While recording with the Nasometer, separator was placed below the subject's nose and above the upper lip and the headset position was adjusted so that the two microphones of the separator will receive the oral and nasal components. For the Nasality visualization system a separator-style measurement handle was used and the position of the handle was adjusted in accordance with the manufacturer's specifications. Five minutes time was provided to each of the participants to get familiarized with the test stimuli. Following familiarization task, the participants were instructed to read the stimuli with the headset/separator handle for the actual recording. They were instructed to start with production of vowels, followed by repetition of CV syllables 3 times each (e.g., pa-pa-pa), finally the oral and nasal sentences at a normal rate, comfortable loudness and pitch. The order of recording on each of the instruments was counter balanced. Second recordings were made in the same session for two instruments to check the test-retest reliability. For Nasometer-II, the headgear was not replaced prior to the second recording.

Measurement of nasalance

Single mean nasalance percentage or nasalance score, was computed by either the nasality visualization system or the Nasometer software. For vowels and sentences the mean nasalance score was analyzed, whereas for CV syllables the mean nasalance score of 3 repeated stimuli (e.g., pa-pa-pa) was taken into consideration. The score for the nasalance were copied to a data sheet by the experimenter and retained for analysis. Thus, the data consists of 74 nasalance scores for each participant (37 using the Nasometer and 37 using the nasality visualization system).

Nasalance scores for each subject were transferred to a data file for statistical analyses. Mean Nasalance scores (%) for the Nasality visualization system and Nasometer II were entered in their original form (to two decimal places). The completed data file was then rechecked against the individual subject data sheets for accuracy of data entry.

Statistical analysis

Statistical Package for Social Sciences (SPSS) version 18.0 (SPSS Inc., Chicago, IL) was used to perform all the statistical analysis. Descriptive statistical measures mean and standard deviation of mean nasalance scores for the all the stimuli were calculated separately for both the instruments. Paired samples t test was performed separately for all the stimuli to verify whether the difference in nasalance scores between the instruments were statistically significant. Within subject repeated measures design was considered for the study. The instrument either Nasometer II or Nasality visualization system and the stimuli (four types) served as the independent variables and the mean nasalance score served as the dependent variable.

Results

1.a. Comparison of nasalance scores with respect to vowels: The mean and standard deviation of nasalance for vowel /a/ was 25.04 (±11.53) and 36.18 (±12.82) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for vowel /i/ was 37.09 (±16.91) and 49.68 (±16.53) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for vowel /u/ was 18.22 (±12.24) and 23.59 (±14.85) respectively with Nasality visualization system and Nasometer instruments. These results are depicted in figure 1. The nasalance values for the vowels /a/, /i/, and /u/ revealed a trend in which the vowel /i/ had the highest nasalance value followed by vowel /a/ and vowel /u/ had the least nasalance value. This trend was commonly observed with both Nasality visualization system and Nasometer instruments.

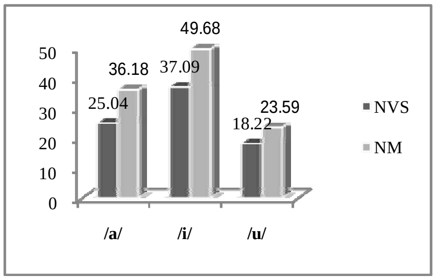

Figure 1: *Mean of nasalance values for vowels /a/, /i/, /u/ with Nasality visualization system (NVS) and Nasometer (NM).*

The mean of the nasalance values for vowels /a/, /i/, and /u/ with Nasality visualization system were lower than that of obtained from Nasometer. This difference is statistically significant at the level of P <0.05 for vowels /a/ and /i/, however, it was not found to be significant for vowel /u/ (Table-1).

Table 1: Statistical significance (p) of difference between nasalance of vowels /a/, /i/, and /u/ obtained with Nasality visualization system (NVS) and Nasometer (NM)

	T	df	Sig. (2-tailed)
NVS /a/ Vs NM /a/	- 4.20	21	0.001
NVS /i/ Vs NM /i/	- 3.75	21	0.001
NVS /u/ Vs NM /u/	- 1.61	21	0.121

1.b. Comparison of nasalance scores with respect to place of articulation and voicing of stop consonants in the context of vowel /a/: The mean and standard deviation of nasalance for /p/ was 12.77 (±8.57) and 17.27 (±8.52) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /t/ was 18.18 (±10.72) and 20.82 (±8.95) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /k/ was 18.14 (±10.96) and 20.23 (±9.99) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /b/ was 30.45 (±12.67) and 27.59 (±13.09) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /d/ was 34.64 (±13.55) and 31.27 (±11.98) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /g/ was 32.64 (±12.93) and 31.41 (±11.50) respectively with Nasality visualization system and Nasometer instruments. These results are depicted in figure 2.

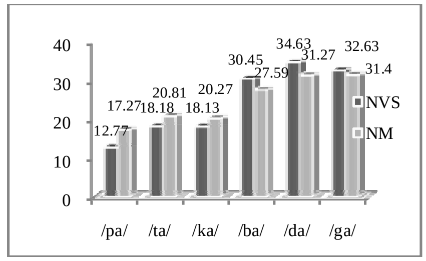

Figure 2: *Mean of nasalance scores for stop consonants with respect to place of articulation and voicing obtained with Nasality visualization system and Nasometer.*

From figure 2 it can be observed that the nasalance values had increased as the place of articulation of the stop consonant moved from bilabial to alveolar or bilabial to velar. This pattern was also observed with voiced stop consonants. Compared to the unvoiced consonants, the voiced consonants (with same place of articulation) obtained higher nasalance values. This trend was commonly observed with both Nasality visualization system and Nasometer instruments. The mean difference of the nasalance values from Nasality visualization system and Nasometer instruments was found statistically significant for /pa/ at p < 0.05 levels. None of the other voiced/unvoiced stop consonants revealed a statistically significant difference between the nasalance values from two instruments. These values are presented in the table 2.

Table 2: Statistical significance (p) of difference between nasalance of unvoiced and voiced stop consonants obtained with Nasality visualization system (NVS) and Nasometer (NM)

	t	df	Sig. (2-tailed)
NVS /pa/ Vs NM /pa/	- 2.41	21	0.02
NVS /ta/ Vs NM /ta/	- 1.42	21	0.16
NVS /ka/ Vs NM /ka/	- 0.91	21	0.37
NVS /ba/ Vs NM /ba/	1.08	21	0.28
NVS /da/ Vs NM /da/	1.16	21	0.25
NVS /ga/ Vs NM /ga/	0.41	21	0.68

1.c. Comparison of nasalance scores with respect to sentences (oral and nasal): The mean and standard deviation of nasalance for oral sentences was 24.80 (±7.88) and 28.27 (±7.87) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for nasal sentences was 54.09 (±6.02) and 59.06 (±5.06) respectively with Nasality visualization system and Nasometer instruments. These values are depicted in figure 3. The nasalance values for the nasal sentences were observed to be higher than the oral sentences. This trend was commonly observed with both Nasality visualization system and Nasometer instruments. These results are depicted in figure 3. Paired sample *t* test did not reveal statistic1ally significant difference between the Nasality visualization system and Nasometer for both oral (t = -2.699, p = 0.01) and nasal sentences (t = -3.709, p = 0.001)

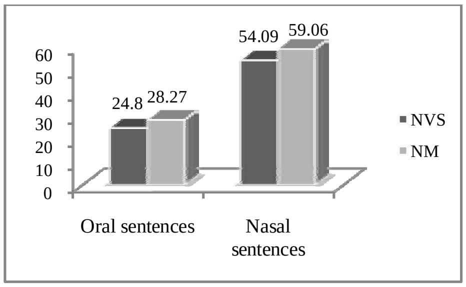

Figure 3: *Mean of nasalance values for oral and nasal sentences obtained with Nasality visualization system (NVS) and Nasometer (NM).*

1.d. Comparison of nasalance scores with respect to all the stimuli: Mean and standard deviations of nasalance score (%) using Nasality visualization system for the stimuli vowels, syllables, oral, nasal sentences were 26.78, 27.35, 24.80, 54.09 respectively. Using Nasometer II, mean nasalance score (%) for vowels, syllables, and oral, nasal sentences were 36.48, 29.85, 28.27, 59.06 respectively. Figure 4 reveals the means and standard deviations for both Nasality visualization system and Nasometer II. Paired sample *t* test revealed significant difference between the nasalance measured by Nasality visualization system and Nasometer instruments across all the stimuli at $p < 0.05$ level of significance (table 3).

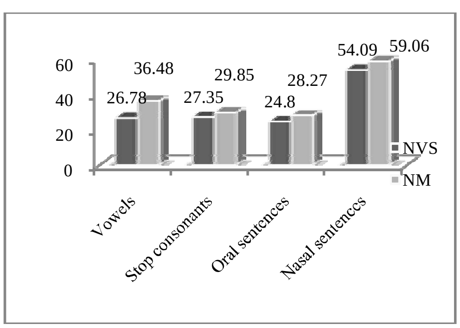

Figure 4: *Statistical significance (p) of difference between nasalance for all the stimuli obtained with Nasality visualization system (NVS) and Nasometer (NM).*

Table 3: Statistical significance (p) of difference between nasalance for all the stimuli obtained with Nasality visualization system (NVS) and Nasometer (NM).

	t	df	Sig. (2-tailed)
NVS-NM (Vowels)	-3.807	21	0.001
NVS-NM (Stop consonants)	-1.656	21	0.113
NVS-NM (Oral Sentences)	-2.699	21	0.013
NVS-NM (Nasal Sentences)	-3.709	21	0.001

2. **Test-retest reliability of the two instruments Nasality visualization system and Nasometer:** Chronbach's alpha for Nasality visualization system indicated acceptable reliability for the vowels (Chronbach's alpha 0.78), good for syllables (Chronbach's alpha 0.87), excellent for nasal sentences (Chronbach's alpha 0.99) but unacceptable for oral sentences (Chronbach's alpha 0.37). Nasometer results indicated excellent Reliability for the vowels (Chronbach's alpha 0.99), acceptable for syllables (Chronbach's alpha 0.76), good for nasal sentences (Chronbach's alpha 0.89), but poor for oral sentences (Chronbach's alpha 0.68). The Chronbach's alpha values for all the stimuli are shown in table 4.

Table 4: *Chronbach's alpha values for Nasality visualization system (NVS) and Nasometer II (NM) across the stimuli.*

	Chronbach's alpha (α) with NVS	Chronbach's alpha(α) With NM
Vowels	0.719*	0.991*
syllables	0.878*	0.769*
Oral sentences	0.370	0.683
Nasal sentences	0.994*	0.896*

* Chronbach's alpha (α) > 0.7 indicate acceptable reliability

Discussion

The purpose of present investigation was to compare nasalance scores for Nasality visualization system and Nasometer II. In the present study the mean nasalance scores were compared between Nasometer II (6400) which is an advanced version of Nasometer (6200) and Nasality visualization system which an advanced version of OroNasal system. Since there is no availability of published studies comparing nasalance scores obtained from Nasality visualization system and Nasometer II, results of the study cannot be compared directly with that of existing literature. The discussion here will be confined to the comparison of trends in nasality with vowel type, place of articulation and voicing of stop consonants and sentence type (oral/nasal) between two instruments.

The results indicated significant difference across vowels with the high nasalance value for the high front vowel /i/ followed by /a/ and /u/ with both Nasality visualization system and Nasometer. These results are in agreement with the previous studies (Mackay & Kummer, 1994; Lewis et al., 2000; Neumann & Dalston, 2001; Gopi Sankar & Pushpavathi, 2008). These authors reported that stimuli weighted with high vowels, especially the high front vowel /i/, produce higher nasalance scores than low vowels on the Nasometer. Gopi Sankar and Pushpavathi (2008) attributed this finding to the articulatory postures assumed during the production of these vowels. The low mid vowel /a/ is an open vowel which creates relatively little resistance to airflow out of the mouth. Therefore the maximum energy is transmitted through the oral cavity. But high vowels /i/ and /u/ impose relatively high resistance to airflow. However, during the production of the /u/ the tongue is placed in close proximity to the velum. This placement may tend to dampen the velar oscillations and thereby reduce acoustic transfer to nasal chamber. Kendrick (2004) provided a physiological explanation for higher nasalance value on vowel /i/. He reported a strong effect of horizontal position of the tongue on the nasalance of vowels.

The mean of the nasalance values for vowels /a/, /i/, and /u/ with Nasality visualization system were significantly lower than that of obtained from Nasometer. This may be attributed to the difference in filter characteristics between two instruments. The Nasometer measures sound intensity in a 300-Hz band around a centre frequency of 500 Hz. Thus, most acoustic energy measured by the Nasometer would be associated with vowels and primarily just the first formant of vowels (Lewis and Watterson, 2003). Whereas the Nasality visualization system features the calculation of nasalance from the amplitudes of the nasal and oral voice components at the voice fundamental frequency, Fo. Therefore the resulting ‘Fo Nasalance’ is less dependent on the particular vowel sound being spoken. Whereas the Nasometer uses a nasalance ratio derived from sound pressure energy in the first formant (the F1 Nasalance) as proposed by Fletcher and Daly (1976) and implemented in his TONAR 2 and in the Kay Elemetrics Nasometer (User Manual, Nasality tutor, Glottal Enterprises, Inc. 2008).

The results of the present study indicated a trend of increase in nasalance values as the place of articulation moved from bilabials to alveolars and bilabials to velars for stop consonants. This trend was observed with both Nasality visualization system and Nasometer instruments. These findings are in agreement with the study by Gopi Sankar and Pushpavathi (2008). These authors using Nasometer II instrument reported higher nasalance values for /k/compared to /t/ and /p/. That is, the nasalance value increased as the place of articulation moved backward in the oral tract. None of the other studies had used the nasalance scores obtained using syllables for comparing the instruments.

Comparison of the nasalance scores obtained using both oral and nasal sentences revealed significant difference between two instruments at $p<0.05$ level of significance. When the instruments were compared for nasalance values across all the stimuli i.e. vowels (average of /a/, i// and /u/), syllables (average of /pa/, /ta/, /ka/, /ba/, /da/ and /ga/), the Nasometer II revealed higher nasalance values than the Nasality visualization system. This finding may be attributed to the difference in the filter settings of the two instruments. However, the nasalance for stop consonants in the context of vowel /a/ was not found to be differing between the instruments.

Chronbach’s alpha reveals good test retest reliability using the Nasality visualization system for three stimuli at a value of $\alpha > 0.70$. However test retest reliability for oral sentences was found to be unacceptable with Chronbach’s alpha less than 0.37. Similar results were obtained with Nasometer II, in which test retest reliability was found to be poor for oral sentences with Chronbach’s alpha less than 0.70. These results are in agreement with the earlier studies by Awan (1998), Seaver et al. (1991), Bressmann (2005) and Neuman and Dalston (2001) who also reported high test retest reliability for nasalance values obtained from Nasometer. In the present study Nasometer as well as Nasality visualization system revealed acceptable test retest reliability for most of the stimuli. Hence, from these findings it may be concluded that both the instruments Nasometer and Nasality visualization system are comparable at least with respect to the test retest reliability.

Conclusions

The Nasometer II revealed higher nasalance values than the Nasality visualization system with statistically significant difference for the most of the stimuli. Therefore, the Nasalance values from the Nasometer II and Nasal visualization system are not interchangeable and cannot be compared directly. The normative data, cutoff scores, sensitivity, specificity and other data of Nasometer might not be applicable to nasalance values obtained from Nasality visualization system. Hence it is essential to consider the establishment of normative and diagnostic efficacy data for Nasality visualization system in future research. The Nasality visualization system provided good test retest reliability which is comparable to that of Nasometer. This finding reveals Nasality visualization system as reliable equipment for nasalance measurement. However, these findings have to be verified with the clinical data. Further, the nasalance values are clinically useful only when it bears a definable and systematic relationship to the listener perception of nasality in patients. Therefore further studies considering listener's perceptual evaluation and using clinical population are essential to compare the clinical utility of Nasality visualization system. If future studies reveal good validity for Nasality visualization system, considering its user friendly hardware, and relatively economical price, may make it an effective alternate for the existing nasalance measuring equipment.

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References

Anderson, R. T. (1996). Nasometric values for normal Spanish-speaking females: Preliminary report. *Cleft Palate Craniofacial Journal*, 33, 333–336.

Awan, S. N. (1996). Development of a low-cost nasalance acquisition system. In Powell, T, ed. *Pathologies of Speech and Language: Contributions of Clinical Phonetics and Linguistics.* New Orleans, LA: International Clinical Linguistics and Phonetics Association, 211–217.

Awan, S. N.(1998). Analysis of nasalance: NasalView. In: Ziegler W, Deger K, eds. *Clinical Phonetics and Linguistics.* London: Whurr-Publishers; 518– 525.

Bressmann, T., Sader, R., Whitehill, T. L., Awan, S. N, Zeilhofer, H. F, Horch, H. H. (2005). Nasalance distance and nasalance ratio: two new measures. *Cleft Palate Craniofacial Journal*, 37, 248–256.

Dalston, R., Warren, D. W., & Dalston. E. (1991). Use of nasometry as a diagnostic tool for identifying patients with velopharyngeal impairment. *Cleft Palate Craniofacial Journal*, 28, 184–188.

Gildersleeve-Neuman, C. E., & Dalston, R. M. (2001). Nasalance scores in noncleft individuals why not zero? *Cleft Palate Craniofacial Journal,* 38, 106–111.

Gopi Sankar, R. & Pushpavathi, M. (2008). Effect of vowels on consonants in nasalance. *Journal of all India institute of speech and hearing, 27,* 3-7.

Fairbanks, G. (1960). *Voice and Articulation Drillbook*, 2nd Ed. New York: Harper and Bros.

Fletcher, S. G. (1978). *Diagnosing Speech Disorders From Cleft Palate.* New York, Grune and Stratton.

Fletcher, S. (1970). Theory and instrumentation for quantitative measurement of nasality. *Cleft Palate journal*, 13, 601–609.

Fletcher, S. G. & Bishop, M. E. (1970). Measurement of nasality with TONAR. *Cleft Palate Journal.*7, 610-621.

Fletcher, S.G., Daly, D.A. (1976). Nasalance in the Utterances of Hearing Impaired Speakers. *Journal of Communication Disorders 9*, 63-73.

Jayakumar, T. (2005). Unpublished research at AIISH, University of Mysore.

Kay Elemetrics Corp. (2003). *Nasometer II Model 6400/6402 Installation, Operations, and Maintenance Manual.*Lincoln Park, NJ: Kay Elemetrics Corp.

Kummer, A. W. (2001). *Cleft Palate and Craniofacial Anomalies.* San Diego: Singular.

Lewis, K. E., Watterson, T., Quint, T. (2000). The effect of vowels on nasalance scores. *Cleft Palate Craniofacacial Journal,* 37, 584–589.

Lewis, K. E., & Watterson, T. (2003). Comparison of nasalance scores obtained from the Nasometer and the NasalView. *Cleft Palate Craniofacacial Journal,* 40, 40–45.

MacKay, I.R., & Kummer, A. W. (1994). *Simplified Nasometric Assessment Procedures.* Lincoln Park, NJ: Kay Elemetrics Corp.

Seaver, E. J., Dalston, R. M., Leeper, H. A., & Adams L. (1991). A study of nasometric values for normal nasal resonance. *Journal of Speech Hearing Research,* 34, 715–721.

Sangeetha, M & Pushpavathi, M. (2008). Nasalence Value for Rainbow Passage: Normative Data for Non- Native Speakers, *Journal of All India Institute of Speech and Hearing*, 27, 22-28.

Tachimura, T., Mori, C., Hirata, S. I., Wada, T. (2000). Nasalance score variation in normal adult Japanese speakers of Mid-West Japanese dialect. *Cleft Palate Craniofacial Journal.* 37, 463–467

Van Lierde, K. M., Wuyts, F.L., De Bodt M, & Van Cauwenberge, P. (2001). Nasometric values for normal nasal resonance in the speech of young Flemish adults. *Cleft Palate Craniofacial Journal,* 38, 112–118.

Van Doorn, J., & Purcell, A.,(1998). Nasalance levels in the speech of normal Australian children. *Cleft Palate Craniofacial Journal,* 35, 287–292.

Watterson, T., Lewis, K., & Deutsch, C., (1998). Nasalance and nasality in low pressure and high pressure speech. *Cleft Palate Craniofacial Journal,* 35, 293–298.

Watterson, T., Lewis, K. E., & Foley-Homan, N. (1999). Effect of stimulus length on nasalance scores. *Cleft Palate Craniofacial Journal,* 36, 243–247.

Whitehill, T. L. (2001) Nasalance measures in Cantonese-speaking women. *Cleft Palate Craniofacial Journal,* 38, 119–125.

DURATION OF VOWELS IN ORIYA: A DEVELOPMENTAL PERSPECTIVE

[1]Venkat Raman Prusty, & [2]Lakshmi Venkatesh

Abstract

The study investigated developmental changes in duration of vowels as produced by native Oriya speaking children. Effects of age, gender, vowel type and voicing of post vocalic consonants and their interactions on the duration of vowels in Oriya were examined. The six vowels in Oriya - /ɔ/, /a/, /i/, /u/, /e/ and /o/ - were targeted for analysis. Duration of target vowel segment V_1 embedded in V_1CV_2 productions of native Oriya speaking children (40 boys and 40 girls) ranging in age from 3-14 years and young adults (10 men and 10 women) were measured using PRAAT software. Results indicated that duration of vowels of this language decreased with increase in age. Intrinsic duration of vowels was dependent upon the type of vowel. Post vocalic voicing lengthened vowel duration as early as three years of age. No significant gender difference was observed. Developmental changes in vowel duration suggested differential control over vowel production. The age at which children's productions reached adult like durations differed by vowel type and the context of vowel production. It was evident that early acquisition of vowel specifications involved an interaction between language specific features and articulatory predispositions associated with phonetic context.

Key words*: vowels, duration, speech development, voicing.*

Speech is a complex, highly skilled motor act, the refinement and stabilization of which continues well into adolescent years (Kent, 1976). The acoustics of speech is the physical event which contains the linguistic message converted to neural code and then to muscular movement. Vowels are often considered to be the central point to understanding of acoustic properties of speech. In addition to the features of the vowel itself, acoustic data on vowels provides information on cues for consonants. The ability to imitate vowel sounds appears to emerge as early as between 12 and 20 weeks of age (Kuhl & Meltzoff, 1996). Such early appearance of vowels makes them important milestones in speech development.

In the process of speech production, phonemes are converted into phonetic units by various rules which are manifested in durational values and temporal variability. Studies on duration of vowel have focused on the durational organization of speech segments, physiologic vs. linguistic nature of production, and the factors that influence the duration of vowels. Vowel duration if explained as phonetic form, the phonological aspect of vowel duration must also be described. Length is a phonological term related to duration. The 'length' and 'duration' are manifested by relative phonetic duration. If the duration of two vowels are different, there may or may not be a phonemic difference in length. Another term often used for phonological length is 'quantity'. The term 'chrone' has been suggested to denote any particular degree of phonetic duration and 'chroneme' to denote a distinctive degree of phonological length (Daniel 1944, cited in Laver, 1995). Durational differences at segmental allophonic level are in terms of differences of coarticulatory adjustment of timing of segments conditioned by different contextual and structural positions. Further, the size of the contextually determined difference is considered to be language specific rather than being language universal (Lehiste & Peterson, 1960).

Vowel duration may also serve linguistic functions differently in different languages. In certain languages, meaningful difference may be associated with the change in the duration of a consonant or a vowel. Vowel duration can be used to signal the stressed syllable (Fry, 1955), mark the word boundaries (Lehiste & Peterson 1959), and identify the syntactic units and to distinguish between similar phonetic segments (Lisker & Abramson, 1964). In some languages, changes in the duration of a sound may be determined by the linguistic environment and may be associated with preceding or following segmental sounds, initial or final position of an utterance, or type and degree of stress. Such durational changes in turn may become cues for the identification of the associated phoneme or pattern of productions (Peterson & Lehiste, 1967). The cues for various morphological processes, syntactic processes, and prosodic and phrasing aspects in a language are accounted for

[1]Audiologist & Speech Pathologist, Dept. of ENT, Head & Neck Surgery, MediCiti Institute of Medical Sciences, Ghanpur, Andhra Pradesh, Email: prustyvr@gmail.com, & [2]Associate Professor, Dr. S. R. Chandrasekhar Institute of Speech & Hearing, Bangalore, Email: lakshmi27@gmail.com

by vowel duration differently for different languages (Lee, 2007).

Research has also found that factors which affect vowel duration are language specific. Language specific effect of voicing context was found by several researchers (Chen, 1970; Mack, 1982; Mitleb, 1984; Leufer, 1989). Similarly language specific effects on vowel duration have been reported for the type of vowel studied (O'Shaughnessy, 1981), gender (Botinis, Bannert, Fourakis & Dzi-mokas, 2003) and age of speakers (Buder & Stoel-Gammon, 2002). Vowel durations vary according to both intrinsic (segment specific) and extrinsic (contextual) specifications. Such variations may both be due to predisposition and cognitive learning. Duration varies differently in different languages as the function of tense-lax distinction, consonant environment, position in the breath group, stress or prominence, speech rate, and even the information content of the word of which they are a part. All of these factors interact in very complex ways (House & Fairbanks, 1953; Fry, 1955; Peterson, 1961; Lehiste, 1972; Klatt, 1973, 1975; Umeda 1975; Allen, 1978; Kent, Netsell & Abbs, 1979; Pickett, 1980).

Research carried out on different aspects of speech segments in children suggest that children's speech compared, to adults' speech, exhibits greater differences in children and adult production in terms of higher pitch and formant frequencies, longer segmental durations, and greater temporal and spectral variability (Eguchi & Hirsh, 1969; Kent, 1976; Kent & Forner, 1980; Smith, 1978; Hillenbrand, Getty, Clark & Wheeler, 1995; Smith & Kenny, 1997). These durational patterns of natural human speech are determined by both physiological disposition and language learning.

Different studies on developmental aspects are evident for obvious neuromotor control and its maturation. Variability of vowel duration has been reported to decrease with age (Eguchi & Hirsh, 1969; Dismoni, 1974; Tingley & Allen, 1975; Kent, 1980); the reduction in variability being considered as an index of maturation of motor control. The developmental changes in use of distinct duration for consonantal contexts have been explained in terms of neuromotor control of speech production which is often disrupted in individuals with several neuromotor dysfunctions (Kent, Netshell & Abbs, 1979). Within the Indian context, several acoustic analysis studies have attempted to explain the factors affecting vowel duration in Indian languages; studies have also been directed at understanding developmental changes in the duration of vowels. Vowel duration and ratio of duration with closure duration was found to serve as cues for gemmination in Hindi (Samudravijaya, 2003). In some languages like Malayalam linguistic boundaries were found to be formed in terms of durational differences in short and long vowels (Jenson & Menon, 1972). Vowel duration was seen to vary with syllable structure, size, vowel type, and variations in production are also dependent on type of vowels (Telugu-Nagamma, 1985, 1988; Tamil- Balasubramanyan, 1981). Languages differ in duration of vowel and VOT (Ravanan, 1993). Duration was seen to be gender dependent in Kannada (Savithri, 1986) and Malayalam (Sasidharan, 1995). The developmental changes in vowel duration is also evident in different Indian languages; the duration is seen to reduce with advancing age (Malayalam- Elizabeth, 1998; Kannada-Sreedevi, 2007; Telugu- Sudeshna, 2008), even range and standard deviation shows similar changes (Sreedevi, 2007; Sudeshna, 2008).

Research on vowel duration in Indian languages have found differences among languages in terms of vowel characteristics such as intrinsic length of vowels, age of acquisition of adult form, and gender differences among other characteristics. These differences across languages provide evidence for the need to study development of acoustic characteristics specific to different languages. Further, languages have specific unique features which cannot be explained on the basis of studies on languages without those features.

Oriya language is widely spoken in the state of Orissa and other regions of West Bengal, Andhra Pradesh and Chhattisgarh. It is one of the major languages of Indo-Aryan group in India. The Oriya phonemes occurring in all varieties, regional as well as social, amount to six vowels and twenty eight consonants (Patnaik, 2000). The Oriya language system has a penultimate pattern of stress (Majumdar, 1970) and vowel ending phonological system for it (Patnaik, 2000). Oriya has six oral vowels & 2 diphthongs with /ɔ/. Vowels of this language are short, i.e. no distinction of long and short vowels at phonemic level (Ramaswami, 1999). Table 1 provides the classification of vowel sounds in Oriya in terms of tongue height, tongue root advancements and mouth opening (Ramaswami, 1999)

Table 1: Classification of Oriya vowels terms of tongue height, tongue root advancements and mouth opening.

Feature	Front	Central	Back
Close (High)	i		u
Half Close (High Mid)	e		o
Half Open (Low Mid)			ɔ
Open (Low)		a	

Certain observations regarding vowels in Oriya can be made. The vowel [ɔ] does not have a front vowel counterpart. This gap in the pattern of all back vowels having a front counterpart exists in Oriya and this makes front-back dimension of vowels to be marked. Languages do not usually tolerate such gaps in the pattern for long time. Whenever there is a gap in some pattern in a language, the drive is either to fill it or to eliminate the odd sound in order to make the phonological system less marked. Bengali and Assamese, which are the sister languages, have a new vowel [E] formed, where as [o] is getting eliminated gradually to make the phonological system less marked or more symmetrical (Ramaswami, 1999).

The current study investigated the age related changes in the duration of vowels produced by Oriya speaking children. A group of adults were also included to compare the vowel durations produced by children with those of the adults. Further, any gender contingent variation in the developmental pattern was also studied.

Method

Participants: A total of 97 children and adults with their native language as Oriya, participated in the study. All participants belonged to the Ganjam district in the state of Orissa. Children in the age range of 3-14 years of age were sampled into eight age groups. Age groups I through V were separated by an interval of one year; age groups VI through VIII were separated by an interval of two years. The adult group consists of participants in the age range of 25-35 years. Developmental changes have been found to be prominent in the age of 4-8 years of age (Kent & Vorperian, 2007). Children in the younger ages were sampled into age groups of shorter intervals in order to allow for analysis of developmental changes if any occurring during the early childhood. An attempt was made to include an equal number of boys and girls participants in each group. All age groups except age group – I included five male and five female participants. Age group – I included four boys and three girls. The details of participants included in the study are provided in Table 2.

Table 2*: Details of Participants*

Age group	Age range	N	females/ males	Age	
	(years; months)			Mean (years; months)	SD* (months)
I	3;0-3;11	7	¾	3;7	0.24
II	4;0-4;11	10	5/5	4;4	0.22
III	5;0-5;11	10	5/5	5;5	0.22
IV	6;0-6;11	10	5/5	6;5	0.29
V	7;0-7;11	10	5/5	7;4	0.28
VI	8;0-9;11	10	5/5	9;5	0.27
VII	10;0-11;11	10	5/5	11;3	0.45
VIII	12;0-13;11	10	5/5	12;11	0.63
IX	Adults 25; 0 – 35; 0	10	5/5	28;4	2.16

*SD – Standard Deviation

Children above the age of five years were recruited from four schools in the Ganjam district in the state of Orissa. Younger children in the age group of 3-5 years were recruited from local aganwadis or balwadis. All participants including children and adults met the following inclusionary criteria as reported by parents in case of children and self in case of the adult group: (1) Oriya as their primary language, (2) typical development of speech and language, (3) no prior enrollment in speech or language intervention (4) normal hearing status and (5) absence of a history of neurological and/or psychological disorder. Oriya was used by all participants for their daily communication needs. All children above five years of age attended schools where the medium of instruction was Oriya. Exposure to English and Hindi was limited to learning these languages in school as part of their curriculum.

Screening: The extended Receptive and Expressive Emergent Language Scale (compiled by All India Institute of Speech & Hearing) was used for evaluation of language skills in children. Children below seven years of age demonstrated age appropriate receptive and expressive language skills. Children above the age of seven years obtained ceiling performance for receptive and expressive language on the extended REELS. All children had normal structure and function of oral articulators as assessed informally. A screening questionnaire for speech, language and listening skills consisting of 'yes/ no', close ended questions was given to teachers and caretakers in the schools and aganawadis respectively in order to confirm the absence of any deficits in speech, language and listening skills among children.

Stimuli: Stimuli consisted of bisyllabic V_1CV_2 words. The first vowel V_1 in the V_1CV_2 words was the target vowel for measuring duration and words consisted of all six vowels in Oriya including /ɔ/, /a/, /i/, /u/, /e/ and /o/. Consonant included only stop consonants. The vowel V_1 was sampled in two post vocalic stop consonant contexts - voiced and unvoiced stop consonants. Bisyllabic words were selected from an initial list of frequently used 40 bisyllabic words and were drawn in consultation with a linguist from corpus of Oriya words which provided the frequency of usage of words (Matson, 1970). The list of 40 bisyllabic words was presented to 10 children in the age group of 10-12 years and 10 young adults. The listeners were instructed to rate the familiarity of words. The rating was done on a three point rating scale with the levels being 'most familiar', 'familiar' and 'unfamiliar'. A total of 23 bisyllabic words rated as most familiar by the listeners were selected as stimuli for the current study. The list of words is included in Appendix- A. The stop consonants in the VCV bisyllabic words included bilabial, dental, retroflex and velar place of articulations. Minimal pairs for all place of articulation of the stop consonant for the post vocalic voiced or unvoiced contexts were not possible due to non availability of real words or familiar words in Oriya meeting the minimal pair condition. Vowels produced in the context of non words and unfamiliar words have been reported to be different from that of real words, familiar and frequently used words (Schwartz, 1995; Vanson, Bolotova, Lennes & Pols, 2004). Repetition of unfamiliar words gives rise to increased difficulty in production resulting in errors or different production patterns in comparison to familiar words (Adams & Gathercole, 1995; Luce & Pisoni, 1998; Munson & Solomon, 2004).

Procedure

Presentation of stimuli: Audio recordings of all bisyllabic and paired words were made from the productions of a native female speaker (age – 25 years) of Oriya with normal speech and language skills. The recorded adult model for each of the stimulus word was audio presented via a computer by the examiner seated in front of the participants. The participants were required to repeat the stimulus word they heard. Three repetitions of each stimulus word were elicited from the participants. The model was presented prior to each repetition.

Instructions: The examiner provided the following instructions to each child while evoking responses to the computer model: "repeat what the sister is saying" or "repeat what you hear". Instructions required imitation of the adult model; feedback regarding accuracy of production was not provided to the participants. In a small subset of cases, children required frequent prompting from the examiner telling them to repeat what they heard. The adult speakers were instructed to repeat what they heard.

Recording: The productions of the participants were audio recorded using a high-fidelity multimedia microphone placed at a distance of six inches from the speaker's mouth. The audio signal was recorded on to the memory of laptop computer (Compaq Pressario-700 with central duel core processor) using the audio recording and acoustic analysis software PRAAT (version 5.0.33; Boersma & Weenink, 2008). A sampling frequency of 44100 Hz was used for audio recordings. Speech samples of individual participants were then stored as wave files. The individual repetition of each word for each participant was parsed into separate files and used for acoustic analysis for measurement of duration.

Measurement of Vowel Duration: The duration of vowels were measured in the acoustic analysis software PRAAT (version 5.0.33; Boersma & Weenink, 2008). Duration of vowels was measured separately for each production by bringing up the parsed wave files in a window. The vowels were identified based upon the regularity of the waveform and vertical striations and formants on the spectrograph. The duration of vowel was measured for the first vowel in the VCV words. The vowel onset and offset were marked on the acoustic waveform by visual inspection. The vowel onset was defined as the first cycle where periodicity began and offset was marked as the end of the last cycle before periodicity ended as displayed on the acoustic waveform. The areas between the onset and offset were highlighted and played back by the examiner to confirm that the highlighted portion of the waveform included the entire duration of vowel. The duration between the two cursor marks was taken as the duration of vowel for the production.

Statistical analysis: All participants produced three repetitions of bisyllabic words with the six target vowels, each divided into two contexts of post vocalic voiced and unvoiced stop consonant. The vowel duration measured were averaged across the three productions of each stimulus word by each participant. Descriptive statistics provided mean and standard deviation of duration of vowels in each age group. MANOVA was performed on vowel duration with vowel type (six vowels), context (post vocalic voiced and unvoiced contexts) as within subjects factors and age groups and gender as between subject factors. MANOVA was followed by appropriate univariate ANOVAs and post hoc comparisons using post hoc Bonferroni tests.

Results

MANOVA performed on duration of vowels revealed significant main effect for vowels ($F(5, 65) = 67.152$, $p = 0.000$) and context ($F(1, 69) = 6527.349$, $p = 0.000$). Interaction between vowels and context was significant ($F(5, 65) = 10.493$, $p = 0.000$). Similarly, interaction of vowels * context * groups was also significant ($F(40, 345) = 1.950$, $p = 0.001$). No other interactions between the variables were significant. As results of MANOVA showed main effects for both the within subject factors of vowels and contexts, separate ANOVAs were performed to analyze age and gender effects on the duration of vowels for each of the six vowels in the two contexts of post vocalic voiced and unvoiced stop consonants. Results are described under the sections of post vocalic voiced or unvoiced consonant contexts.

Post vocalic voiced consonant context

The mean values of duration of each vowel in the post vocalic voiced stop consonant context produced by male and female speakers in the adult group are depicted in Figure 1. Irrespective of gender of participants, the vowel /a/ had the longest duration and vowel /i/ had the shortest duration. The duration of vowels in post vocalic voiced context was longest for participants in age group I (3 to 3 years 11 months). In the productions of children in age group I, duration of vowel /ɔ/ was 154.1ms, /a/ was 157.8ms, /i/ was /142.8/, /u/ was 146.1 ms, /e/ was 147.1 ms and /o/ was 151.1ms. The durations of vowels were shortest in the adult group in comparison to children. In the adult productions, the duration of vowel /ɔ/ was 110.7 ms, /a/ was 122.2 ms, /i/ was 93.3 ms, /u/ was 98.1 ms, /e/ was 99.1 ms, /o/ was 102.3 ms.

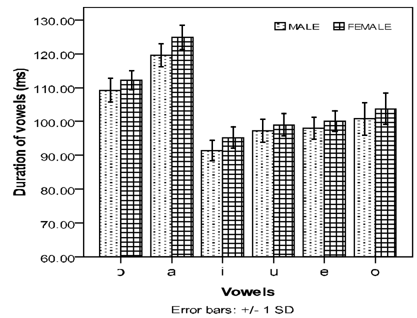

Figure: 1. *Mean of durations of vowels in the post vocalic voiced consonant context produced by male and female speakers in the adult group.*

Mean duration of six vowels in the post vocalic voiced context obtained by male and female participants in the nine participant groups is depicted in Table 3. Figure 2 shows the mean values of duration of vowels across all nine age groups. It is evident from the figure that the duration of all six vowels in the post vocalic voiced stop consonant showed a decrement with increase in age. Two-way ANOVAs performed on duration of each of the six vowels in post vocalic voiced context revealed significant differences with age. Duration did not significantly differ between male and female participants for vowels /ɔ/, /i/, /u/, /e/ and /o/ except for vowel /a/ ($F(1, 69) = 4.432$, $p = 0.039$). There was no interaction between gender and age group for any of the vowels.

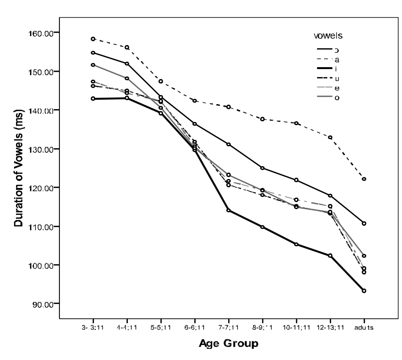

Figure 2: *Mean values of duration of all six vowels in the post vocalic voiced stop consonant context produced by participants in the nine age groups*

Table 3*: Group mean and standard deviations (in parenthesis) of duration (msec) of six vowels in the post vocalic voiced context.*

Age Groups	Gender	/ɔ/	/a/	/i/	/u/	/e/	/o/
3-3;11yrs	Male	150.4 (15.00)	154.5 (21.55)	141.6 (14.44)	145.2 (15.49)	145.6 (16.86)	148.2 (14.77)
	Female	159.11 (15.03)	162.1 (17.65)	144.2 (14.66)	147.1 (14.63)	149.0 (16.97)	154.9 (12.56)
	Total	154.1 (14.48)	157.8 (18.77)	142.8 (13.34)	146.1 (13.87)	147.1 (15.54)	151.1 (13.22)
4-4;11 yrs	Male	148.8 (16.51)	154.2 (18.86)	141.1 (13.29)	144.0 (14.89)	143.3 (15.45)	145.2 (13.39)
	Female	155.1 (16.23)	158.0 (14.06)	145.0 (13.65)	145.9 (14.64)	145.2 (15.74)	151.0 (13.66)
	Total	152 (15.79)	156.2 (15.81)	143.1 (12.86)	145 (13.97)	144.3 (14.74)	148.2 (13.12)
5-5;11 yrs	Male	141.8 (13.11)	144.9 (10.84)	138.3 (11.41)	141.3 (12.16)	139.8 (12.30)	136.8 (13.03)
	Female	144.6 (13.30)	149.7 (10.36)	139.9 (11.37)	142.8 (12.42)	144.7 (12.05)	144.2 (13.30)
	Total	143.3 (12.85)	147.4 (10.32)	139.2 (10.77)	142.1 (11.62)	142.3 (11.78)	140.5 (13.00)
6-6;11 yrs	Male	135.1 (11.27)	140.0 (9.07)	128.1 (9.76)	130.1 (10.29)	129.6 (10.02)	129.2 (12.41)
	Female	137.63 (11.05)	144.6 (8.54)	131.1 (9.41)	133.3 (10.42)	131.7 (9.73)	130.9 (12.30)
	Total	136.4 (10.61)	142.3 (8.66)	129.6 (9.18)	131.8 (9.91)	130.7 (9.38)	130.1 (11.69)
7-7;11 yrs	Male	129.0 (9.17)	137.2 (8.73)	111.8 (9.15	118.9 (9.22)	120.3 (7.54)	122.3 (11.70)
	Female	133.0 (9.11)	144.2 (8.24)	116.2 (8.92)	122.3 (9.08)	122.9 (7.36)	124.1 (11.09)
	Total	131.1 (8.87)	140.8 (8.83)	114.1 (8.83)	120.6 (8.81)	121.7 (7.16)	123.2 (10.79)
8-9;11 yrs	Male	122.9 (6.34)	137.1 (5.52)	108.3 (6.19)	115.9 (7.10)	117.5 (5.44)	118.2 (10.49)
	Female	127.0 (6.03)	138.1 (7.65)	111.2 (6.19)	120.1 (7.09)	121.1 (5.20)	120.2 (10.60)
	Total	124.9 (6.22)	137.7 (6.31)	109.8 (6.05)	118 (7.04)	119.3 (5.36)	119.2 (10.00)
10-11;11 yrs	Male	120.2 (5.26)	135.5 (4.35)	104.3 (5.78)	114.3 (5.34)	115.8 (4.78)	114.2 (7.89)
	Female	123.6 (4.43)	137.9 (4.41)	106.2 (5.81)	116.0 (4.98)	117.8 (4.70)	115.4 (8.50)
	Total	121.9 (4.93)	136.5 (4.39)	105.3 (5.56)	115.2 (4.96)	116.8 (4.59)	114.9 (7.76)
12-13;11 yrs	Male	116.1 (4.42)	131.8 (4.74)	101.3 (4.85)	112.3 (4.12)	114.1 (4.30)	112.4 (5.73)
	Female	119.6 (4.42)	133.9 (3.79)	103.4 (4.39)	114.2 (3.93)	116.1 (4.11)	114.8 (6.05)
	Total	117.9 (4.56)	132.9 (4.2)	102.4 (4.5)	113.3 (3.94)	115.2 (4.1)	113.6 (5.7)
Adult group	Male	109.2 (3.52)	119.5 (3.45)	91.3 (2.98)	97.2 (3.35)	98.0 (3.19)	100.8 (4.82)
	Female	112.1 (2.89)	124.8 (3.53)	95.2 (3.09)	99.0 (3.27)	100.0 (3.03)	103.7 (4.59)
	Total	110.7 (3.41)	122.2 (4.34)	93.3 (3.52)	98.1 (3.26)	99.1 (3.12)	102.3 (4.71)

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Post hoc Bonferroni analyses performed to analyze vowel duration between the age groups for each of the six vowels showed no difference in the duration of vowels produced by children in the age groups of 3-4 years, 4-5 years, 5-6 years and 6-7 years. Children in the age group of 7-8 years did not show any difference in vowel duration from the children in the age group of 8-10 years, 10-12 years and 12-14 years, but showed difference from the productions of adult group. No significant difference was found for duration between the age groups of 10-12 years, 12-14 years and adult group. Age related changes in the vowel duration were observed above the age of seven years and continued till the age at which children's productions were similar to those by adults. The age at which children's productions reached adult like durations differed by vowel type. For vowels /e/ and /u/, children achieved adult like production by 8-10 years of age. For vowels /ɔ/, /a/, /i/ and /o/ children achieved adult like productions by 10-12 years of age.

Post vocalic unvoiced consonant context

Figure 3 shows the mean values of duration of each vowel in the post vocalic unvoiced stop context as produced by male and female speakers in the adult group. As seen from the figure, irrespective of the gender of participants in the adult group, the vowel /a/ had the longest duration and the vowel /i/ had the shortest duration. The duration of vowels in post vocalic unvoiced context was longest for participants in group I (3 to 3 years 11 months).

The duration of vowels produced by children in age group I ranged from 116.7 ms for vowel /i/ to 132.6 ms for vowel /a/. The durations of all vowels were shortest in the adult group. In the adult productions, the duration of vowel /ɔ/ was 77.3 ms, /a/ was 81.2 ms, /i/ was 62.1 ms, /u/ was 67.2 ms, /e/ was 70.5 ms and /o/ was 73.4 ms.

Mean duration of six vowels in the post vocalic unvoiced context obtained by male and female participants in the nine participant groups is depicted in Table 4. Figure 4 shows the mean values of duration of vowels across all nine age groups. It is evident from the figure that the duration of all six vowels in the post vocalic unvoiced stop consonant showed a decrement with increase in age.

Two-way ANOVAs performed on duration of each of the six vowels in post vocalic unvoiced context revealed a significant decrease in duration with age; no significant difference occurred between duration of vowels produced by female and male participants. There was no interaction between age groups and gender.

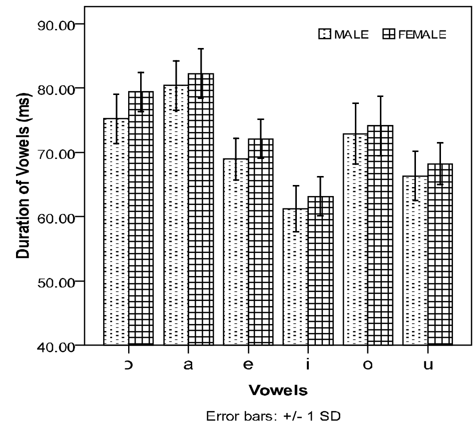

Figure 3: *Mean of durations of vowels in the post vocalic unvoiced consonant context produced by male and female speakers in the adult group.*

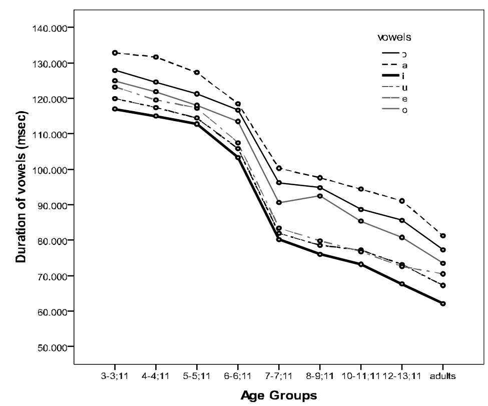

Figure 4: *Mean values of duration of all six vowels in the post vocalic unvoiced stop consonant context produced by participants in the nine age groups*.

Post hoc Bonferroni analyses between vowel durations in post vocalic unvoiced context produced by participants in the different age groups showed that there was no difference among children in the production of vowels /i/ and /u/ in the age groups of 3-4 years, 4-5 years, 5-6 years and 6-7 years. For vowels /ɔ/, /a/, /e/ and /o/, there was no significant difference in the duration of vowels among children in the age groups of 3-4 years, 4-5 years and 5-6 years. Children in the age group 6-7 years did not show any difference from children in the age group of 5-6 years for all vowels, but showed difference from that of productions by children in the age group of 4-5 years for vowel /ɔ/, /a/ and /o/. The duration of vowels /ɔ/, /a/, /i/ and /o/ did not show any significant difference in the duration produced by children in the age groups of 10-12 years, 12-14 years and adult group.

Table 4: *Group mean and standard deviations (in parenthesis) of duration (msec) of six vowels in the post vocalic unvoiced context.*

Age Groups	Gender	/ɔ/	/a/	/i/	/u/	/e/	/o/
3-3;11 yrs	Male	127.1 (15.44)	131.3 (19.44)	115.1 (14.28)	119.6 (15.67)	122.1 (17.74)	123.5 (16.21)
	Female	128.6 (15.66)	134.3 (12.08)	118.7 (14.45)	120.1 (14.62)	124.2 (17.17)	126.3 (14.20)
	Total	127.7 (14.19)	132.6 (15.50)	116.7 (13.24)	119.8 (13.93)	123.0 (16.02)	124.7 (14.17)
4-4;11 yrs	Male	124.0 (16.54)	131.1 (16.23)	114.1 (13.32)	115.7 (14.35)	117.8 (15.70)	120.5 (13.93)
	Female	124.9 (16.38)	132.1 (11.96)	115.8 (13.73)	118.9 (14.32)	121.1 (15.89)	123.1 (13.80)
	Total	124.5 (15.53)	131.6 (13.45)	114.9 (12.78)	117.3 (13.62)	119.5 (14.99)	121.8 (13.14)
5-5;11 yrs	Male	120.2 (13.50)	127.0 (12.44)	111.5 (11.61)	112.6 (12.43)	115.4 (12.91)	116.8 (13.48)
	Female	122.2 (13.19)	127.4 (12.22)	113.9 (11.46)	116.2 (12.07)	119.1 (11.54)	119.1 (13.14)
	Total	121.2 (12.63)	127.2 (11.63)	112.7 (10.95)	114.4 (11.70)	117.26 (11.70)	117.9 (12.61)
6-6;11 yrs	Male	114.9 (11.50)	117.1 (9.59)	102.0 (9.97)	104.3 (10.31)	105.8 (10.40)	111.6 (12.66)
	Female	118.3 (11.40)	119.9 (8.46)	104.5 (9.84)	107.3 (10.71)	109.0 (10.48)	115.3 (12.29)
	Total	116.6 (10.94)	118.5 (8.66)	103.2 (9.43)	105.8 (10.03)	107.4 (9.99)	113.5 (11.92)
7-7;11 yrs	Male	93.2 (9.35)	96.6 (8.63)	78.3 (9.39)	81.1 (9.15)	82.1 (8.52)	86.5 (11.78)
	Female	99.0 (9.26)	103.9 (7.97)	82.0 (9.10)	82.7 (9.08)	84.6 (8.56)	94.6 (10.98)
	Total	96.1 (9.29)	100.2 (8.73)	80.2 (8.92)	81.9 (8.64)	83.4 (8.16)	90.6 (11.55)
8-9;11 yrs	Male	90.8 (6.23)	94.2 (6.02)	74.2 (6.31)	77.0 (7.04)	77.8 (5.62)	88.7 (10.88)
	Female	98.8 (6.31)	100.8 (5.68)	77.8 (6.63)	80.0 (7.11)	81.8 (5.75)	96.2 (10.54)
	Total	94.8 (7.25)	97.5 (6.52)	76.0 (6.38)	78.5 (6.86)	79.8 (5.74)	92.5 (10.83)
10-11;11 yrs	Male	85.2 (5.83)	90.7 (4.82)	72.1 (5.88)	76.3 (5.00)	75.2 (5.00)	83.9 (7.39)
	Female	92.2 (5.29)	98.0 (3.04)	74.2 (5.89)	78.0 (5.20)	78.2 (4.82)	86.7 (7.81)
	Total	88.7 (6.41)	94.3 (5.40)	73.1 (5.66)	77.1 (4.88)	76.7 (4.88)	85.3 (7.32)
12-13;11 yrs	Male	83.3 (4.93)	86.9 (4.18)	66.9 (5.04)	72.3 (4.08)	72.2 (4.74)	79.1 (5.82)
	Female	87.8 (5.07)	95.1 (4.23)	68.4 (4.96)	74.0 (3.96)	72.9 (4.65)	82.3 (5.24)
	Total	85.5 (5.27)	91.0 (5.86)	67.7 (4.78)	73.1 (3.89)	72.5 (4.44)	80.7 (5.49)
adult group	Male	75.2 (3.83)	80.3 (3.82)	61.1 (3.55)	66.3 (3.85)	68.9 (3.23)	72.8 (4.69)
	Female	79.3 (3.01)	82.2 (3.83)	63.1 (3.04)	68.1 (3.22)	72.0 (3.04)	74.1 (4.64)
	Total	77.3 (3.93)	81.2 (3.73)	62.1 (3.28)	67.2 (3.49)	70.5 (3.39)	73.4 (4.44)

Age related changes in the vowel duration in the post vocalic unvoiced context were observed above the age of five years and continued till the age at which children's productions were similar to those by adults. The age at which children's productions reached adult like durations differed by vowel type. For vowels /ɔ/, /a/, /i/ and /o/ children achieved adult like productions by 10-12 years of age. For vowels /e/ and /u/, children did not achieve adult like production even by 14 years of age.

Discussion

Vowel type

Vowel /a/ in the post vocalic voiced context was found to be the longest (Mean = 122.2 ms) and vowel /i/ in the post vocalic unvoiced context (Mean = 81.2 ms) was found to be the shortest vowel produced by the adults in the current study. Longer durations for vowel /a/ in comparison to other vowels have been reported in various languages such as English (Peterson & Lehiste, 1960; Danish, House & Fairbanks, 1963), Thai (Abramson, 1962) and Swedish (Elert, 1964). Overall, the results of research on vowel duration across different vowels indicate that when all other factors are kept constant, the intrinsic duration of vowels is dependent on the nature of vowel in terms of high vs. low, open vs. closed among other such contrasts. The longer duration of vowel /a/ may be attributed to its inherent nature of being an open and low vowel (Myers, 2005).

Similar pattern of findings for vowel /a/ to be longest and /i/ as shortest the shortest vowel were reported by Nagamma, (1985) in Telugu and Sreedevi (2003) in Kannada. However, other studies done in Telugu showed the duration of vowel /o/ to be longest among all short vowels, and duration of /a:/ to be longest among all long vowels (Prabhavathi, 1990; Girija & Sridevi, 2003). Results of study done by Sudeshna (2008) in Telugu speaking children revealed that vowel /i/ to be shortest in all short vowels in voiced and unvoiced context, but the longest vowel from her study was vowel /e/ in adult productions. Nagamma (1985) stated that in isolated words, the back vowels are longer than the front vowels whereas in connected speech, the front vowels are longer than the back vowels. Savithri (1984) found that a low vowel had longer duration than a high vowel in Kannada.

Context differences

Vowel durations of vowels in the context of unvoiced stop consonant were significantly lower than durations of vowels in the context of voiced stop consonants. The results of the current study in terms of differences in vowel duration between voiced and unvoiced contexts are in consonance with studies done in English (Peterson & Lehiste, 1960; House, 1961; Raphael 1975; Raphael, Dorman & Geffener, 1980; Hillenbrand, Getty, Clark & Wheeler, 1995), Telugu (Nagamma, 1988; Prabhavathi, 1990; Girija & Sreedevi, 2003; Sudeshna, 2008), Tamil (Balasubramanian, 1981), Kannada (Sreedevi, 2007) and Hindi (Lampp & Reklis, 1986). Peterson & Lehiste (1960) stated that the duration of vowel with any intrinsic nucleus duration, changes according to the following consonants. He classified vowels into tense and lax and stated that this feature was dependent on the manner and voicing of following consonants.

Vowel lengthening as a function of voicing of following consonant has been postulated as a language universal phenomena (Chen, 1970; O'Shaughnessy, 1981). Further the quantity of this effect is thought to be determined by language specific phonological structure (Chen, 1970). The study by Chen (1970) observed differences in the duration of vowels in voicing contexts in four different languages namely French, Russian, Korean and English. In the four languages investigated, all four showed similar pattern of vowel lengthening for voicing contexts, but the effect was found to be varying among languages.

Development effects

The duration of vowels decreased as age increased from Age group I (3 to 3 years 11months) to Group IX (adult group). This decrease in vowel duration with increase in age occurred in both contexts of post vocalic stop consonant and was observed in the productions of both male and female speakers. These findings were supported by several other researches in English speaking children and adults (Naeser, 1970; Smith & Kenny, 1997; Krause, 1982; Krause, Fisher & Wigthman, 1982; Chen, 1970). Evidence of decrease in vowel duration has been inferred as developmental changes occurring due to neuromotor maturation controlling aspects of production.

The age at which children's productions reached adult like durations differed by vowel type and the context of vowel production. Children achieved adult like productions of vowels /ɔ/, /a/, /i/ and /o/ in both post vocalic voiced and unvoiced stop consonant contexts, by the age of 10-12 years. Children achieved adult like productions for vowels /e/ and /u/ in the post vocalic voiced context by the age of 8-10. However, their productions of vowels /e/ and /u/ in the post vocalic unvoiced context did not reach adult like productions even by the age of 14 years of age. The difference in developmental changes for unvoiced and voiced context suggests differential control over production mechanism. This difference in duration of vowels between voiced consonants context and unvoiced consonant context was demonstrated in productions of children as young as 21 months of age and occurred even before the control of final consonant voicing (Nasser, 1970). In contrast, the results of DiSimoni (1974) showed that the use of longer vowel before a voiced consonant in comparison to unvoiced consonant occurred only after six years of age. It was found that vowels preceding unvoiced consonant were smaller in duration across age groups, where as vowels preceding voiced consonants increased with age. Similar results have been found by Smith, 1978; Kent & Forner, 1980; Lee, Potamianos & Narayanan, 1999; Sreedevi, 2007).

These findings can be attributed to the neuromuscular maturation as the child grows older and improved control over the articulatory movements. In the study by Lee and colleagues (Lee et.al., 1999), children reached adult form of productions around 15 years of age. Results of Sudeshna (2008) indicated that duration of vowels decreased as age increased; the productions of children in the age group of 13-15 years of age reached adult like form. Krause (1982) showed that vowels before voiced consonants became progressively shorter with an increase in age. It was also revealed that children of at least three years of age over-lengthened vowels before voiced consonants to affect the necessary durational differences between voicing contexts. In contrast, the results of DiSimoni (1974) showed that duration of vowels before an unvoiced consonant did not change and duration of vowel before a voiced consonant increased with age. But the difference between the duration of a vowel in both contrast seemed to increase as age increased.

Differences in the patterns of changes in duration of vowels in post vocalic voiced and unvoiced consonant were observed. The differences in reaching adult form for some vowels in different context as found in the present study may also be explained as individual differences in intrinsic nature of each vowel. The difference may also suggest that vowel duration continues to develop beyond adolescent years for some vowels; adult like forms are achieved at different ages for different tasks (Lee, et al., 1999). All speech production characteristics do not mature on the same schedule for a given child (Smith & Kenny, 1998).

In general, the pattern of developmental changes was context dependent and affected the duration of vowel in a similar way regardless of the vowel type and its intrinsic duration. The effect of context was different for age groups, indicating the context specific production, i.e. differentiated production of vowel duration for voicing of following consonant was present at young age and developed as age increased. The vowel effect was not different in different age groups. Both of these results indicated that the difference in production in context and vowel type might be linguistically controlled though physiologically determined. Acquisition of vowel productions in early stages has been postulated as involving an interaction between both language specific features and articulatory predispositions associated with phonetic context (Buder & Stoel-Gammon, 2002). Other physiologically determined aspects being the gender difference which was not observed in any of the six vowels in both contexts in any age groups.

Gender effects

No difference was found in the duration of vowels produced by female and male speakers in the current study for most vowels. The one exception was vowel /a/ in voiced context, where female produced significantly longer duration than males. The productions by female speakers were found to be longer than the productions by male speakers in different age groups (Hillenbrand, 1995; Lee, et.al., 1999; Savithri, 1986; Sreedevi, 2007; Simpson, 2001; Simpson & Ericsdotter, 2003). The possible explanations for such a difference have been based on sociophonetic aspect that female speakers speak more clearly (Simpson, 2001; Simpson & Ericsdotter, 2003). However, in their studies on sex-specific durational differences in English and Swedish, Simpson and Ericsdotter (2003) showed contrary results in terms of female's production of back rounded vowels being shorter in comparison to the productions of their male counterparts. This was attributed to the use of less reduced forms by female speakers.

In the present study however, no significant difference between male and female speakers occurred for most of the six vowels in both the contexts. The findings of the current study are in consonance with the findings of Sreedevi (2007) who reported that the duration of vowel in male and female speakers did not differ significantly in the age group of 7-8 years of age. Sudeshna (2008) reported gender difference in the productions of older children in the age group of 13-15 years and adults; females produced duration of vowels significantly longer than that of males. Gender difference in terms of female speakers producing longer duration of vowels than males, is reported to be present in some languages such as Greek and Albanian and absent in language such as English and Ukrainian (Botinis, 2003). Gender effects have been reported in the studies on vowel durations to be different based on other factors like stress pattern as studied by Ericsdotter and Ericsson (2001). The result of their study in Swedish language showed that duration of words without any contrastive stress was longer when produced by males than that by females and the difference was significant only for /i/ and /u/. However, in case of words carrying contrastive stress, female vowels were always longer than male, and the difference was significant for all vowels leading to the conclusion that females used greater durational contrast when compared to males.

Implications of the study: This study provided preliminary data on the temporal characteristics of vowels in Oriya. The data adds to the much needed corpus of acoustic characterization of vowels and consonants in Indian languages. Comparative data between different age groups of children (3-14 years) and adults in terms of effects of different contexts on different types of vowels were provided. Such data may serve useful in analysis of speech of children with speech sound disorders as well as adults with neurological disorders. The values of vowel duration may inform models for speech recognition and synthesis for Oriya language.

Limitations and future directions: The current study was limited to measuring duration of vowels only in the VCV words for singleton productions. Future studies of vowel duration in Oriya can include stimuli of different syllable structure and syllable size. Production involving the repetition task may be compared with those of reading or spontaneous speech to understand temporal characteristics in different context. Other temporal features such as syllable duration, word duration, voice onset time, duration of consonants need to be studied from a developmental perspective. Acoustic analysis of speech of children with speech disorders will provide insights into development of speech motor control among children and point to disruptions if any in the control of speech.

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References

Abramson, A. S. (1962). The vowels and tones of standard Thai: Acoustical measurements and experiments. Bloomington, IN: Indiana University Research Center in Anthropology, Folklore and Linguistics.

Adams, A. M., & Gathercole, S. E. (1995). Phonological working memory and speech production in pre-school children. *Journal of Speech and Hearing Research, 38*, 403–414.

Allen, G. D. (1978). Vowel duration measurement: A reliability study. *Journal of the Acoustical Society of America. 63*(4), 1176-1185.

Balasubramanian, T. (1981). Duration of vowels in Tamil. *Journal of Phonetics, 9,* 151-161.

Botinis, A., Bannert, R. M., & Dzi-mokas D. (2003). Multilingual focus production of female and male focus production. *6th International Congress of Greek Linguistics.* Greece: University of Crete.

Buder, E. H., & Stoel-Gammon C. (2002) American and Swedish children's acquisition of vowel duration: Effects of vowel identity and final stop voicing. *Journal of the Acoustical Society of America, 111,* 1854–1864.

Chen, M. (1970). Vowel length variation as a function of the voicing of the consonant environment. *Phonetica, 22*(3), 129-159.

Disimoni, F. G. (1974). Influence of consonant environments on the duration of vowels in the speech of three, six and nine years old children. *Journal of Acoustical Society of America, 55,* 362-363.

Eguchi, S., & Hirsh. I. J. (1969). Development of speech sounds in children. *Acta Otolaryngologica Supplementum 257,* 1-51.

Elizabeth, J. A. (1998). Analysis of speech of Malayalam speakers. Research at AIISH, Dissertation Abstracts, IV, 43, (2003).

Elert, C-C. (1964). Phonologic studies of quantity in Swedish. Stockholm: Almqvist & Wiksell.

Ericsdotter, C., & Ericsson, A. M. (2001). Gender differences in vowel duration in read Swedish: Preliminary results. In Proc. Fonetik 2001, XIVth Swedish Phonetics Conference. Working Papers of the Department of Linguistics, Lund University, 49, 34–37.

Fry, D. B. (1955). Duration and intensity as physical correlates of linguistic stress. *Journal of the Acoustical Society of America, 27,* 765-768.

Girija, P. N., & Sridevi, A. (2003). Duration rules for vowels in Telugu. Paper presented at Oriental COCOSDA Workshop 2003, Singapore.

Hillenbrand, J., Getty, L. A., Clark, M. J., & Wheeler, K. (1995). Acoustic characteristics of American English vowels. *Journal of the Acoustical Society of America, 97,* 3099–3111.

House, A. S., & Fairbanks, G. (1953). The influence of consonantal environment upon the secondary acoustical characteristics of vowels. *Journal of the Acoustical Society of America, 25,* 105–113.

House, A. S. (1961). On vowel duration in English. *Journal of the Acoustical Society of America, 33,* 1174-1178.

Jensen, P. J. & Menon, K. M. N. (1972) Physical analysis of linguistic vowel duration. *Journal of the Acoustical Society of America, 52,* 708-710.

Kent, R. D. (1976). Anatomical and neuromuscular maturation of the speech mechanism: Evidence from acoustic studies. *Journal of Speech and Hearing Research, 19,* 421-447.

Kent, R. D., Netsell, R., & Abbs, J. H. (1979). Acoustic characteristics of dysarthria associated with the cerebellar disease. *Journal of Speech and Hearing Research, 22,* 627-648.

Kent, R. D., & Forner, L. L. (1980). Speech segment durations in sentence recitations by children and adults. *Journal of Phonetics, 8,* 157 - 168.

Kent, R. D. (1980). Motor skill components of speech development. Paper presented at the Annual convention of the American Speech-Language Hearing Association, November 21-24, Detroit: Michigan.

Kent, R. D., & Vorperian, H. K. (2007). Vowel acoustic space development in children: A synthesis of acoustic and anatomic data. *Journal of Speech, Language, and Hearing Research, 50,* 1510-1545.

Klatt, D. H. (1973). Interaction between two factors that influence vowel duration. *Journal of the Acoustical Society of America, 55,* 1102-1104.

Klatt, D. H. (1975). Vowel lengthening is syntactically determined in a connected discourse. *Journal of Phonetics, 3,* 1208-1221.

Kuhl, P. K., & Meltzoff, A. N. (1996). Infant vocalizations in response to speech: vocal imitation and developmental change. *Journal of Acoustical Society of America, 100(4 Pt 1),* 2425-38.

Krause, S. E. (1982). Developmental use of vowel duration as a perceptual cue to postvocalic stop consonant voicing. *Journal of Speech and Hearing Research, 25,* 388-393.

Krause, S. E., Fisher, H. B., & Wightman, F. L. (1978). Developmental use of vowel duration in perception and production. *Journal of the Acoustical Society of America, 64, (S1),* S114-S115.

Lampp, C. & Reklis. H. (2004). Effects of coda voicing and aspiration on Hindi vowels. Poster presented at the Annual meeting of the Acoustical Society of America, New York, May, 2004.

Laver, J. (1995). *Principles of Phonetics.* Cambridge: Cambridge University Press.

Lee, E. (2007). Acoustic effects of prosodic domain-initial vowels in Korean. *Saarbrucken,* 6-10.

Lee, S., Potamianos, A., & Narayanan, S. (1999). Acoustics of children's speech: Developmental changes of temporal and spectral parameters. *Journal of the Acoustical Society of America 105*(3), 1455–1468.

Lehiste, I., & Peterson, G. (1959). Vowel amplitude and phonemic stress in American English. *Journal of the Acoustical Society of America, 31,* 428-435.

Lehiste, I., & Peterson, G. (1960). Duration of syllabic nuclei. *Journal of Acoustical Society of America, 32,* 693-703.

Lehiste, I. (1972). The timing of utterances and linguistic boundaries. *Journal of the Acoustical Society of America, 51,* 2018-2024.

Lisker, L., & Abramson, A. S. (1964). A cross-language study of voicing in initial stops: Acoustical measurements. *Word, 20,* 384-422.

Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear & Hearing, 19,* 1-36.

Mack, M. (1982). Voicing-dependent vowel duration in English and French: Monolingual and Bilingual production. *Journal of the Acoustical Society of America, 71,* 173-178.

Majumdar, P. C. (1970). A historical phonology of Oriya, *Calcutta Sanskrit college research series, Original from the University of Michigan,* Iii.

Matson, D. M. (1970). *Oriya word count.* The Oriya language textbook series. Cornell University, Ithaca, New York.

Mitleb, F. (1984). Timing of English vowels spoken with an Arabic accent. In, F. Mitleb, Mousa, et al. (Eds.) Proceedings of the Tenth International Congress of Phonetic Sciences. Netherlands Phonetic Archives, 700-705.

Munson, B., & Solomon, N. P. (2004). The effect of phonological neighbourhood density on vowel articulation. *Journal of Speech, Language and Hearing Research, 47,* 1048-1058.

Myers, S. (2005).Vowel duration and neutralization of vowel length contrasts in Kinyarwanda. *Journal of Phonetics, 33,* 427-446.

Naeser, M. (1970). The American child's acquisition of differential vowel duration. The Wisconsin Research and Development Center for Cognitive Learning, Technical Report no 144.

Nagamma R. K. (1985). Phonetic conditioning of duration of vowels and consonants in Telugu. *Osmania Papers in Linguistics, 11,* 54-83.

O'Shaughnessy, D. (1981). A study of French vowel and consonant durations. *Journal of Phonetics, 9,* 385-406.

Patnaik, B. N. (2000). Oriya language, In I. Ramchandani (Ed.), *Students' Britannica India, Volumes 1-5, (pp.* 133). *Popular Prakashan.*

Peterson, G. E. (1961). Parameters of vowel quality. *Journal of Speech and Hearing Research, 4,* 10-29.

Peterson, G., & Lehiste, I. (1967). Duration of syllable nuclei in English. In I. Lehiste (Ed.), *Readings in acoustic phonetics* (pp. 191-201). Cambridge, MA: The M.I.T. Press.

Prabhavathi Devi, M. (1990). Vowel length in English and Telugu. Department of Phonetics spoken English, Hyderabad: CIEFL.

Pickett, J. M. (1980). The sounds of speech communication: A primer of acoustic phonetics and speech perception. Baltimore: University Park Press.

Ramaswami, N. (1999). Common linguistic features in Indian languages: Phonetics. Central Institute of Indian Languages, Mysore.

Raphael, L. J., Dorman, M. F., & Geffner, D. (1980). Voicing-conditioned durational differences in vowels and consonants in the speech of three-and four-year old children. *Journal of Phonetics, 8,* 335–341.

Raphael, L. J. (1975). The physiological control of durational differences between vowels preceding voiced and voiceless consonants in English. *Journal of Phonetics, 3,* 25-33.

Ravanan, M. P. (1993). Cross linguistic study of some temporal parameters. Research at AIISH, Dissertation Abstracts, III, 101, (2002).

Samudravijaya, K. (2003). Durational characteristics of Hindi phonemes in continuous speech. Technical Report- April 2003, Tata Institute of Fundamental Research, Mumbai.

Sasidharan, P. (1995). Vowel duration in Malayalam language. Research at AIISH, Dissertation Abstracts, III, 171, (2002).

Savithri, S. R. (1986). Durational analysis of Kannada vowels. *Journal of Acoustical Society of India, 14* (2), 34-41.

Schwartz, R. G. (1995). Effect of familiarity on word duration in children's speech: A preliminary investigation. *Journal of Speech and Hearing Research, 38*, 76-84.

Simpson, A. P. (2001). Dynamic consequences of differences in male and female vocal tract dimensions. *Journal of the Acoustical Society of America, 109*(5), 2153–2164.

Simpson, P. A., & Ericsdotter, C. (2003). Sex-specific durational differences in English and Swedish. In Proc. XVth ICPhS, (pp 1113–1116), Barcelona.

Smith, B. L. (1978). Temporal aspects of English speech production: A developmental perspective. *Journal of Phonetics, 6,* 37-67.

Smith, B. L., & Kenney, M. K. (1997). An assessment of several acoustic parameters in children's speech production development: Longitudinal data. *Journal of Phonetics, 26*, 95-108.

Smith, B. L., & Kenny, M. K. (1999). A longitudinal study of the development of temporal properties of speech production: Data from 4 children. *Phonetica, 56,* 73-102.

Sreedevi, N. (2007). Effect of age on vowel duration in Kannada. *Journal of All India Institute of Speech and Hearing, 26,* 35-40.

Sudeshna, P. (2008). A study on duration of vowels in Telugu: A developmental perspective, Unpublished Masters Dissertation. Osmania University, Hyderadad.

Tingley, B. M., & Allen, G. D. (1975). Development of speech timing control in children. *Child Development, 46,* 186-194.

Umeda, N. (1975). Vowel duration in English. *Journal of the Acoustical Society of America, 58*, 434-445.

Vanson, R. J. J. H., Bolotova, O., Lennes, M., & Pols, L. C. W. (2004). Frequency effects on vowel reduction in three typologically different languages (Dutch, Finnish, Russian). *Proc. Interspeech,* 1277-1280.

Appendix- A

Stimuli used to measure the duration of Oriya vowels

Vowel	Post vocalic voiced stop consonant context	Post vocalic unvoiced stop consonant context
/ɔ/	/ɔba/, /ɔd̪a/, /ɔɽa/	/ɔpa/, /ɔʈa/, /ɔt̪i/
/a/	/ad̪i/, /abe/, /age/	/ape/, /at̪ɔ/
/i/	/iɽa/	/iʈa/, /it̪i/
/u/	/uɽa/, /ud̪a/, /uga/	/uka/, /upi/
/e/	/ebe/,	/eka/, /et̪e/
/o/	/od̪a/	/oʈɔ/

EFFECT OF PALATAL LIFT PROSTHESIS ON LARYNGEAL AERODYNAMICS AND VOICE QUALITY IN SUB-MUCOUS CLEFT PALATE

[1]Navya A., [2]Gopi Kishore P. & [3]Pushpavathi M.

Abstract

The closure of velopharyngeal port is essential for normal resonance in speech. The abnormality of velopharyngeal port (VPP) in persons with cleft palate leads to compensatory changes in laryngeal valving and higher prevalence of voice disorder. Palatal lift prosthesis is one of the rehabilitation options for individuals with submucous cleft palate (SMCP). The present study investigates the influence of velopharyngeal dynamics on laryngeal airway dynamics and voice quality in an individual with SMCP using palatal lift prosthesis. Laryngeal aerodynamic parameters such as Sub-Glottic Pressure (SGP), Laryngeal Airway Resistance (LAR), Mean Air Flow Rate (MAFR) and Dysphonia Severity Index (DSI) were obtained with and without using prosthesis before and after 20 minutes of vocal loading task. Age and gender matched subjects served as controls. The results indicated variations in the laryngeal aerodynamics (LAR) and voice quality following vocal loading in individual with SMCP than compared to normal subjects. The reduction in the measures of the laryngeal resistance and subglottic pressure in the individual with SMCP was noticed with the use of palatal lift prosthesis. These variations indicate the influence of palatal lift prosthesis in reducing the laryngeal compensatory behavior.

Keywords: *Palatal Lift, Dysphonia Severity Index, Laryngeal Resistance, Sub Glottal Pressure.*

Voice is one of the most important parameters of speech production. Production of normal speech requires coordination between the phonatory, respiratory, articulatory and resonatory systems. Individuals with cleft lip and palate (CLP) exhibit anatomical deformities of oral structures leading to the voice disorders. The voice characteristics in individuals with CLP are characterized as breathy, hoarse, and soft. This is usually due to increased respiratory, muscular effort, and hyper-adduction of the vocal folds while attempting to close the velopharyngeal valve (Kummer, 2008). The prevalence of hoarseness in the cleft palate population is reported as 5.5% (Robison & Otteson, 2011).

The hoarseness in individuals with cleft lip and palate is explained with different hypothesis, the most common being laryngeal compensation for abnormal velopharyngeal valving. The laryngeal aerodynamic parameters have been found to be a useful tool in discriminating normal vocal function from pathologic voice. Aerodynamic parameters are influenced by a number of anatomical features and physiological events, such as the driving pressure arising from the respiratory system, the constriction, size and timing of movements of the vocal cords, together with the size, shape and biomechanical properties of the vocal tract as a whole (Miller & Daniloff 1993). Based on relationship that exists between laryngeal aerodynamics, laryngeal structure and physiology, it would be expected that aerodynamic parameter values would vary with respect to the different types of cleft and compensatory strategies used by individuals with cleft lip and palate.

The importance of aerodynamic measures in the assessment and treatment of individuals with voice disorders is increasingly being recognized (Baken, 1987). Grillo and Verdolini (2008) investigated the efficacy of laryngeal aerodynamic parameters such as laryngeal resistance and vocal efficiency in distinguishing pressed, normal, resonant, and breathy voice qualities in vocally trained subjects. The authors concluded that, out of the two parameters the laryngeal resistance was efficient in distinguishing the pressed from normal and breathy voice qualities. In a similar study by Grillo, Perta, and Smith (2009) laryngeal resistance was found to be successful in distinguishing the pressed, normal, and breathy voice qualities in vocally untrained females.

Mc Williams, Bluestone, and Musgrave (1969) reported that some children with velopharyngeal inadequacy may use "generalized laryngeal tension" as a compensatory valving strategy, "even in the absence of glottal fricatives and plosives".

[1]Junior Research Fellow, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: navyaaslp@gmail.com, [2]Lecturer in Speech Pathology, AIISH, Mysore-06, Email: gopiaslp@gmail.com & [3]Professor in Speech Pathology, AIISH, Mysore-06, Email: pushpa19@yahoo.co.in

They believed that children with borderline velopharyngeal function would be most likely to engage in this type of compensatory laryngeal activity (McWilliams, Bluestone, & Musgrave, 1969). Leeper, Macrae, and Mcknight (1994) compared the transglottal airflow in children with inadequate VPI and with adequate VP closure. They reported higher transglottal airflow in the group with inadequate closure.

Zajac (1995) studied the laryngeal airway resistance (LAR) levels with respect to the velopharyngeal closure in children with non cleft palate and 14 children with cleft palate grouped into incomplete and complete velopharyngeal closure. They were instructed to perform syllable repetition task while occluding the nostrils and targeting typical adult speech. Results indicated that children with incomplete VP closure exhibited significantly higher laryngeal resistance. Guyette, Sanchez and Smith (2000) conducted a study on thirty six children with cleft palate, ten with incomplete VP closure and twenty six with complete VP closure. They were asked to repeat /ipipipipipipipi/ at a rate of 1.5 syllables per second. The authors concluded that laryngeal airway resistance (LAR) and transglottal pressure were significantly higher and transglottal airflow was significantly lower in individuals with cleft palate exhibiting incomplete closure. They attributed this to the velopharyngeal insufficiency (VPI) which demands for increased muscular effort at the laryngeal level to compensate for the potential velopharyngeal (VP) air leak while speaking.

Brustello, Paula, and Yamashita (2010) conducted a study to explore whether individuals with marginal velopharyngeal dysfunction modify the laryngeal resistance as a strategy to achieve complete velopharyngeal closure during speech. The study was conducted on nineteen individuals with cleft palate and eighteen normal age and gender matched control group during the production of syllable /pa/ with and without nasal occlusion. They concluded that the individuals studied with marginal velopharyngeal closure did not modify laryngeal resistance. They had slightly lower laryngeal resistance values than individuals without cleft. They attributed this to the variations in the oro-nasal flow, resulting from the physiological adjustments occur as a compensatory strategy. This physiological adjustment is to maintain levels of intraoral air pressure for the stable production of speech, such as increased laryngeal airflow (Warren, 1986).
Most of the studies used the perceptual methods to describe the vocal behaviour in individuals with velopharyngeal disorder. Objective studies on vocal quality in subjects with cleft palate are sparse. Lewis, Andreassen, Leeper, Macrae, and Thomas (1993) reported higher frequency perturbation (jitter) in the voice of individuals with cleft lip and palate. Van Lierde, Claeys, De Bodt, and Van Cauwenberge (2004) used a multi parametric measure Dysphonia Severity Index (DSI) to analyze the voice quality in 21 children with cleft palate. The DSI is based on the weighted combination of the following selected set of voice measurements: highest frequency (F0-high in Hz), lowest intensity (I-low in dB), maximum phonation time (MPT in s), and jitter (%). The DSI ranges from +5 to -5 for, respectively, normal and severely dysphonic voices. The more negative the patient's index, the worse is the vocal quality (Wuyts, Bodt, Molenberghs, Remacle, Heylen, & Millet, 2000). The male children with cleft palate showed an overall vocal quality of +0.62 with the presence of a perceptual slight grade of hoarseness and roughness. The female children had a DSI value of +2.4 reflecting a perceptually normal voice. Results concluded that irrespective of the type of cleft, all subjects demonstrated a significantly lower DSI-value in comparison with the available normative data.

Vocal loading is one of the tasks to know the functioning of the laryngeal system and voice quality. Vocal loading is defined as prolonged loud use of voice and has four distinct phases: warm up (adapting to the voicing task), performance (continuance of the voicing task), vocal fatigue (perceived increase of physical effort associated with voicing, physical changes to the larynx), and rest or recovery (Jilek, Marienhagen, & Hacki, 2004; Vintturi, Alku, Sala, Sihvo, &Vilkman, 2003). Prolonged loud reading protocols vary with regard to loudness levels, tasks, and total reading times (20 min to 2 hr), making direct comparisons between study outcomes difficult. Most reported outcome data include some combination of before and after acoustic, aerodynamic, stroboscopic, and perceptual measures. Evidence suggests that for the healthy voice, a minimum of 1 hour is required to induce symptoms of fatigue (Gelfer, Andrews & Schmidt, 1991, 1996; Stemple, Stanley & Lee, 1995).

Webb, Starr, and Moller (1992) have conducted a study to measure the effects of extended speaking on resonance and voice quality of eight individuals with cleft palate and eight age and gender matched normal individuals using a five point rating scale for perceptual measurement. Results revealed that five cleft subjects became more nasal, two less nasals, and one did not change. Three normal subjects became more nasal and five did not change. The two cleft subjects who changed the most became less nasal. The mean of the vocal quality change ratings was higher for the normal. However, quality improved for three cleft and six normal subjects, and did not change for two cleft and one normal subject. From the results they interpret that resonance changes were greater and voice quality changes less, for the cleft group, but that changes were not significant nor always in the direction of increased hypernasality or decreased vocal quality.

The management of these individuals requires multidisciplinary team approach which includes an active role of the prosthodontist and speech pathologist. Considerable attention is focused on documenting the efficacy of prosthesis (Pinto, Dalben & Krook, 2007; Seunghee, Hyunsub, Zhi, & Kuehn, 2003). Palatal lifts are used as non - surgical interventions for management of velopharyngeal dysfunction (VPD) (Marsh & Wray, 1980). Palatal lift prosthesis aims to move the soft palate in a posterior and superior direction to aid in the closure of the velopharyngeal gap. Use of palatal lift prosthesis is considered as an effective method of treatment in improving articulation in individuals with velopharyngeal dysfunction (La Velle & Hardy 1979).

Pushpavathi and Sreedevi (2004) reported increased formants frequencies and better velopharyngeal closure with the use of palatal lift prosthesis in an individual with submucous cleft palate. Tachimura, Kotani, and Wada (2004) studied the effect of palatal lift prosthesis on children with repaired cleft palates exhibiting hypernasality and nasal emission with increased nasalance scores. They reported that individuals with repaired cleft palate exhibited decreased nasalance scores while using palatal lift prosthesis.

Despite of high prevalence of voice disorders, in individuals with CLP only few studies have documented the aerodynamic aspects of vocal functions. It is essential to explore the aerodynamic characteristics in individuals who have undergone prosthodontic management as this parameter provides insight into the physiological aspects of the laryngeal aerodynamics. As there are no studies on laryngeal aerodynamics using prosthesis, the present study is an exploratory study to analyze the laryngeal dynamics in prosthodontic management. Hence, this study is aimed to study the effect of velopharyngeal mechanism on laryngeal aerodynamics and voice quality of speech in an individual with submucous cleft palate using palatal lift prosthesis.

The objectives of the study were to investigate (a) The Sub Glottic Pressure (SGP), Mean Airflow Rate (MAFR), Laryngeal Airflow Resistance (LAR), and Dysphonia Severity Index (DSI) in open (without palatal lift) versus closed (with palatal lift) velopharyngeal port (VPP) conditions between subject and controls, (b) The combined effects of velopharyngeal port (VPP) dynamics and vocal loading on Sub Glottic Pressure (SGP), Mean Airflow Rate (MAFR), Laryngeal Airflow Resistance (LAR), and Dysphonia Severity Index (DSI) in the subject and controls and (c) Compare velopharyngeal closure with and without prosthesis conditions using nasoendoscopy.

Method

Subject

A female aged 35 years with unrepaired submucous cleft palate served as subject of in the present study. The cleft palate rehabilitation team (plastic surgeon, prosthodontist, orthodontist, psychologist & speech-language pathologist) was involved in the evaluation and management of the subject. The evaluation included oral peripheral examination, speech analysis using perceptual rating scales and objective methods. Based on the assessment, the participant was diagnosed as having velopharyngeal dysfunction with unrepaired submucous cleft palate exhibiting hypernasality and misarticulations. The plastic surgeon recommended surgical management of SMCP. However, the client was not motivated to undergo the surgery. Hence, she was recommended to use palatal lift prosthesis by the prosthodontist.

An impression of the palate was obtained and palatal lift prosthesis was prepared by the prosthodontist. Initially the participant was provided with the anterior portion of the palatal obturator and she was counseled to use consistently for two weeks to get adapted to the prosthesis. Following this period, the prosthesis was extended to the velar portion of the palate and the subject was provided one month time to get adapted to the prosthesis. The subject was recommended to attend speech therapy regularly. However, she was able to attend twice in a week (total 6 sessions, 45 minutes each session). Speech assessment was done using Kannada articulation test (Babu, Ratna, & Betagiri, 1972). She was diagnosed as normal articulation with hypernasality. Hence, the speech therapy goals were aimed at reducing the nasality and improving the oral resonance. Based on the feedback from the participant and perceptual analysis of speech, prosthodontist made suitable modifications to the velar section of the prosthesis until adequate velopharyngeal closure was achieved. Nasoendoscopy was done with and without palatal lift prosthesis in situ to examine the velopharyngeal closure. All the acoustic recordings with prosthesis condition were done after confirming adequate velopharyngeal port closure through the nasoendoscopy images.

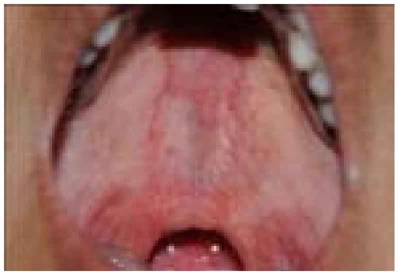


Figure 1: *Submucous cleft palate*

Figure 2: *Palatal lift Prosthesis*

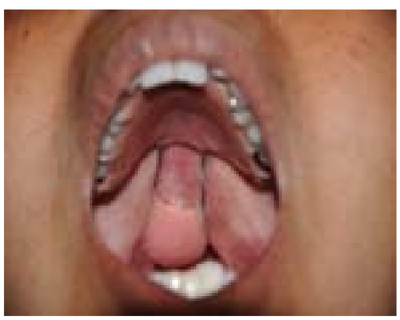


Figure 3: *Palatal lift prosthesis in Situ*

As the present study considered a single subject in the experimental group, the results have to be compared with control group. In order to analyze and compare the aerodynamic measures, five age and gender matched subjects were considered as the control group. The subjects with no history of smoking, laryngeal pathology under respiratory disorder and normal resonance were selected as control subjects .The control subjects were not using any medication

Procedure

To induce vocal loading effect, the subject was asked to read a story in Kannada from an elementary textbook. The subject was proficient in reading Kannada as it was her first language. The subject was instructed to read continuously for 20 minutes, as few studies (Remacle, Finck, Roche, & Morsomme, 2011; Niebudek-Bogusz, Kotylo, & Sliwinska-Kowalska, 2007) have reported 30minutes of continuous reading can induce vocal fatigue and lead to variations in acoustic characteristics of voice. Another study by Titze, Svec, and Popolo (2003) reported that beyond 17minutes of continuous vocalization or about 35 minutes of continuous reading can cause changes in the vocal fold tissue morphology and their response to vibrational pattern. As the previous studies have shown that 30 minutes of vocal loading task can induce variations in voices, the present study considered 20 minutes for vocal loading task at the level of 75-80 dB SPL. A practice trail helped her to monitor loudness (by visual feedback) during recording of the stimuli. All the recordings were obtained with a distance of 15cm between the microphone and subject. The Sub Glottic Pressure (SGP), Mean Airflow Rate (MAFR), Laryngeal Airflow Resistance (LAR), and Dysphonia Severity Index (DSI) were measured. The speech sample was recorded in four conditions a) without vocal loading and open velopharyngeal port (VPP) b) After inducing the effect of vocal loading and open VPP c) without vocal loading and closed VPP d) After inducing the effect of vocal loading and closed VPP. The recordings were made immediately after reading task for 20 minutes. The aerodynamic parameters were extracted from the above four recordings. The experiment was done before any actual vocal loading initiated by the subject. The subjects were instructed not to indulge with any vocal loading task or prolonged usage of voice prior to the data collection. The subjects were informed about few vocal hygiene tips after the experiments. Nasoendoscopy was done to analyze the velopharyngeal port closure only during the production of prolonged /a: / vowel with and without prosthesis condition. For the controls the below recordings were done before and after vocal loading task (Reading).

Measuring SGP, MAFR, and LAR

The instrument *Aeroview 1.4.4 version*, Glottal Enterprises was used to obtain the data related to aerodynamics of speech. The instrument consists of pressure and airflow transducers mounted onto the face mask, the computer interface and the dedicated application software for analyzing the data. The instrument was calibrated for air pressure and air flow transducers. The subjects were instructed to hold the mask firmly to cover nose and mouth with the intraoral tube placed between the lips and above the tongue. Then the subjects were instructed to produce the repetitions of nine CV syllables /papapapapapapapapa/ into the mask at a comfortable pitch and loudness with equal stress on each syllable. To ensure equal rhythm, subjects were trained until they produce the syllable trains at the appropriate pace and comfortable loudness level.

The subjects were allowed for two practice runs before the actual recording. The recordings in which the syllable production rate was between 2.0 – 3.5 per second were considered for further analysis. Three peak to peak measurements were made and their average was taken to obtain the Sub Glottic Pressure, Mean Air Flow Rate, and Laryngeal Airway Resistance values. Sub Glottal Pressure was estimated based on the measures of peak (intraoral air pressure) during the production of the consonant /p/. Mean Air Flow Rate was derived from the oral airflow measures recorded during the production of vowel segment of the /apapapapapapapa/. The measures (Sub Glottal Pressure & Mean Air Flow Rate during voicing) were subsequently used by the aerodynamic system to calculate Laryngeal Airway Resistance as shown in the figure 1 during comfortable sustained phonation.

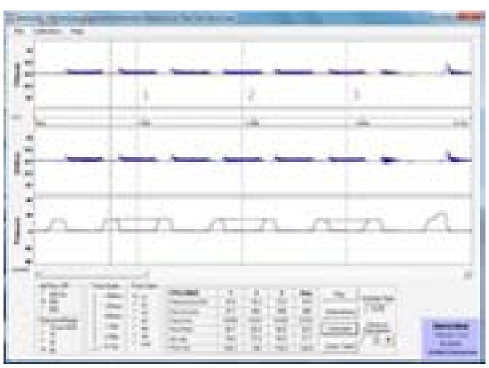


Figure 4: *The display of laryngeal parameters by Aeroview.*

Calculating DSI

Dysphonia severity index (DSI) was used to quantify the quality of voice. The raw scores required for DSI measurement are highest frequency (High F0), lowest intensity (low I), jitter % and maximum phonation time (MPT). The DSI scores were calculated from the raw scores using the regression equation - DSI=0.13xMPT+0.0053xF0 (high)-0.26xI (low)-1.18x jitter (%) +12.4. The more negative the patient's index is, the worse is his or her vocal quality (Wuyts, De Bodt, Molenberghs, Remacle, Heylen, & Millet, 2000). The results were analyzed and discussed in terms of graphical representation. These measures were obtained as described below.

Measuring MPT

MPT was measured for the vowel /a/, sustained at the subject's habitual pitch and loudness in free field (without any mouthpiece) and in sitting position. The experimenter instructed the subject on the task and also modeled the procedure demonstrating taking deep breath followed by phonation at a comfortable pitch as long as she could do. The length of sustained phonation was measured in seconds with the aid of the *Computerized Speech Lab (Kay Pentax, Model 4500)***.**

Measuring high F0 and Low I

The highest frequency and the lowest intensity were measured with the *Voice Range Profile* from the *CSL (Kay Pentax, Model 4500).* The procedure described by Heylen, Wuyts, Mertens, De Bodt, Pattyn, and Croux (1998) was used to measure the lowest intensity and highest frequency from the *Voice Range Profile*. After some vocal warm-up exercises, the subjects were instructed to inhale in a comfortable way and to sustain the vowel /a/ for at least 2 seconds using a "habitual pitch" and loudness. The subject vocalized at his or her lowest and highest frequencies using the softest and greatest intensities at each frequency extreme.

Measuring Jitter %

The acoustic parameters F0, jitter, and shimmer were obtained from the *Multi Dimensional Voice Program* (MDVP) of *CSL (Kay Pentax Corp, model 4500).* A mid vowel segment on a sustained /a/ at habitual loudness and pitch was used.

Statistical Analysis

Descriptive statistical analysis was used.

Results and Discussion

1) Effect of velopharyngeal mechanism on laryngeal aerodynamic parameters between the subject and controls.

Sub-Glottic Pressure (SGP), Laryngeal Airway Resistance (LAR), Mean Airflow Resistance (MAFR) and Dysphonia Severity Index (DSI) were measured with and without prosthesis conditions in the subject and controls. The results are mentioned in table 1 and figure 5.

Table 1: *SGP, MAFR, LAR and DSI with and without prosthesis across subjects.*

Condition	SGP (cmH2O)	MAFR (L/sec)	LAR (cmH2O / L/sec)	DSI (Index)
NP	5.28	0.38	71	4.78
WP	3.87	0.39	9	5.05
CSBR	4.86 (1.83)	0.31 (0.16)	17.08 (4.06)	4.26 (1.60)

*(*standard deviations for control subjects are mentioned within the brackets, NP-No prosthesis, WP-With prosthesis, CSBR: Control Subject before reading)*

The laryngeal aerodynamic parameters were found to be increased in SMCP compared to normal subjects. However, the variation was observed in these values after using the prosthesis. The results depict reduction in the measures of the laryngeal resistance and subglottic pressure after using the prosthesis. The laryngeal airway resistance reduced more with respect to the subglottic pressure. The variation of these parameters was not consistent across the conditions. There were minimum differences in DSI, SGP and MAFR values with and without prosthesis conditions. The mean values of DSI and MAFR were higher in the experimental subject than control subject.

The present study reported the decrease in the laryngeal resistance and sub glottal pressures with prosthesis and this may be attributed to the reduction in the laryngeal involvement in the speech regulation mechanism, which appears to depend on velopharyngeal closure (Zajac, 1995). The results of the study is also in agreement with Guyette, Sanchez, and Smith (2000) findings who reported that individuals with cleft palate exhibit increased laryngeal airway resistance (LAR) and transglottal pressure and reduced transglottal airflow to achieve complete closure of the velopharyngeal valve. This may be due to velopharyngeal dysfunction (VPD) which demands for increased muscular effort at the laryngeal level to compensate for the potential velopharyngeal (VP) air leak while speaking. Hence, the use of prosthesis might have resulted in better velopharyngeal closure reducing the need of the respiratory and laryngeal system to compensate for the speech production. In the present study, the reduced laryngeal airway resistance reflects the reduced laryngeal compensatory mechanism for speech production.

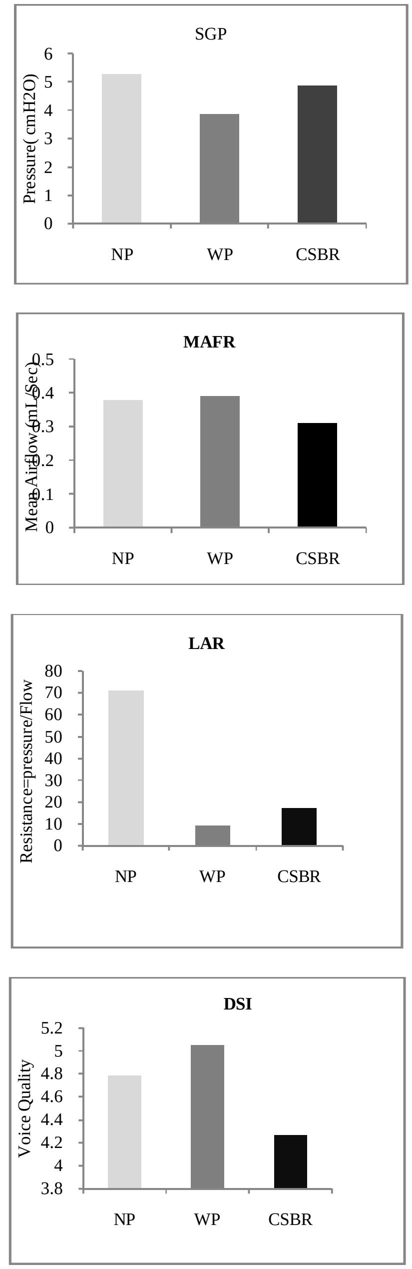


Figure 5*: SGP, MAFR, LAR and DSI with and without prosthesis across subjects.*

Van Lierde, Claeys, De Bodt, and Van Cauwenberge (2004) reported significant lower DSI values in cleft population than normal subjects. In the present study the DSI measures of the subject was at par with the controls. The contradicting results may be due to the dissimilarities or differences present in the methodological issues of the study. The study conducted by Van Lierde, Claeys, De Bodt, and Van Cauwenberge (2004) includes 28 children with unilateral or bilateral cleft palate and the present study included only an individual with submucous cleft palate and control subjects.

All the aerodynamic and laryngeal parameters did not change after using the prosthesis but only few of these parameters (Laryngeal airway resistance and subglottic pressure) have shown variations after using the prosthesis. These results were supports the findings of Pushpavathi and Sreedevi (2004), Tachimura, Kotani, and Wada (2004) who reported decrease in nasality after using the palatal lift prosthesis in individuals with submucous cleft lip and palate.

2) Comparison of SGP, MAFR, LAR and DSI with and without prosthesis before and after vocal loading across subjects.

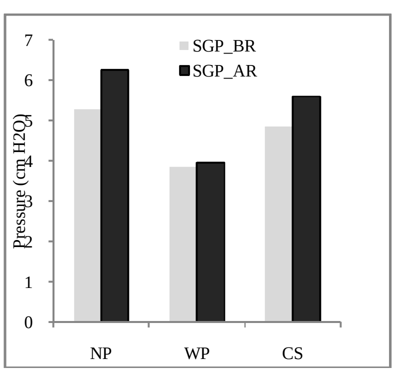
The Sub-Glottic Pressure (SGP), Laryngeal Airway Resistance (LAR), Mean Airflow Resistance (MAFR) and Dysphonia Severity Index (DSI) were measured with and without prosthesis before and after vocal loading in the subject and controls. The results are mentioned in table 2 & figure 6.

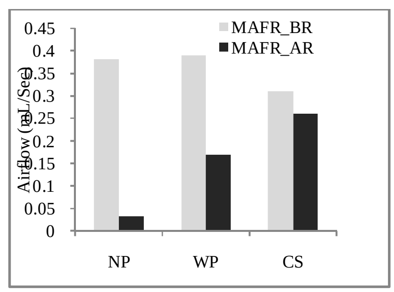
Table 2: *SGP, MAFR, LAR and DSI with and without prosthesis before and after vocal loading across subjects*

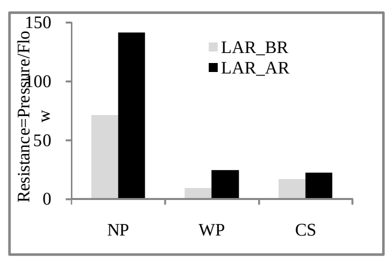
Condition	SGP (cmH2O)	MAFR (L/sec)	LAR (cmH2O / L/sec)	DSI (Index)
NPBR	5.28	0.38	71	4.78
NPAR	6.25	0.033	142	2.48
WPBR	3.87	0.39	9	5.05
WPAR	3.95	0.17	24.8	3.88
CSBR	4.86 (1.83)	0.31 (0.16)	17.08 (4.06)	4.26 (1.60)
CSAR	5.59 (1.20)	0.26 (0.11)	22.75 (7.46)	2.48 (1.25)

**Note: NPBR-No prosthesis and before reading, NPAR- No prosthesis after reading, WPBR-with prosthesis before reading, WPAR-With prosthesis after reading, CSBR: Control Subject before reading, CSAR-With prosthesis after reading.*

The results illustrate that after vocal loading task the sub glottal pressure and laryngeal airway resistance increased. However, there was a decrease in the mean airflow rate and dysphonia severity index in all the conditions i.e., with and without prosthesis between the subject and controls. But, the increase in the laryngeal airway resistance was more in the subject than the controls while the other measures (SGP, MAFR & DSI) have shown less variation. The effect of vocal loading was reduced with the use of prosthesis as reflected in the laryngeal aerodynamic measures shown in the above table. With the use of prosthesis, differences in the laryngeal aerodynamic measures before and after vocal loading were less than that of the without prosthesis condition and also relatively similar to that of the controls.







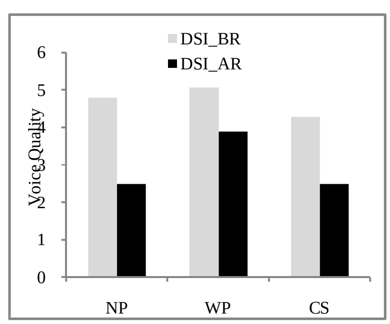


Figure 6: *SGP, MAFR, LAR and DSI with and without prosthesis before and after reading across subjects.*

The increased subglottal pressure and laryngeal resistance were observed across all the conditions in both subject and controls after vocal loading task. This can be due to the prolonged usage of the laryngeal mechanism (Webb, Starr, & Moller, 1992). The results also indicate reduction in the DSI and MAFR measures following vocal loading tasks in both the conditions of subject (with and without prosthesis) and controls. Webb, Starr, and Moller (1992) studied the effects of extended speaking on resonance and voice quality in eight adults with cleft palate exhibiting hypernasality and matched with non cleft adults. The results of the study were ambiguous. Hence, they concluded that resonance changes were greater and voice quality changes were less for the cleft group, but not indicating a consistent pattern of changes always. Whereas in the present study, consistently reduction in the MAFR and DSI across the subjects and conditions were seen. These contradictory results may be because of the variations in the methodology i.e., subject selection, number of subjects, method of analysis. The variations in the DSI values may be largely due to the variations in the jitter (frequency perturbations) after undergoing the vocal loading task. According to Vilkman, Lauri, Alku, Sala, and Shivo (1999) vocal loading task can lead to phonatory threshold shift and increased jitter percentage, which might reflect an impairment of the viscoelastic characteristics of the vocal folds.

This indicates that while using the prosthesis the effect of vocal loading was relatively less than without prosthesis condition. This can be attributed to the reduced physical effort on the vocal folds, which minimizes the vocal fatigue due to the better velopharyngeal closure. The study supports the findings of Warren (1986) who described that larynx has potential to regulate speech aerodynamic events in velopharyngeal dysfunction state

3) Comparison of velopharyngeal closure with and without prosthesis conditions.

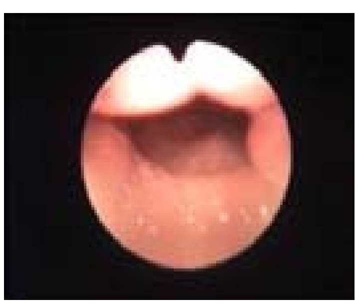


Figure 7: *Without Prosthesis*

Figure 8: *With Prosthesis*

The physiological assessment was done using the nasoendoscopy model number CS 400 to measure the velopharyngeal (VP) closure pattern with and without using prosthesis in individual with submucous cleft palate. Velasco, Ysunza, Hernandez, and Marquez (1988) point out that, individuals with velopharyngeal insufficiency are most likely to demonstrate a coronal closure pattern. Since the musculus uvulae occludes the major portion of the velopharyngeal sphincter in this pattern, its underdevelopment in submucous cleft palate would contribute significantly to the velopharyngeal insufficiency noted in these patients.

In the present study, nasoendoscopic images were taken when the subject phonated prolonged /a:/ in both the conditions (with & without prosthesis). The velopharyngeal closure without prosthesis (Fig. 7) showed gap while an improved closure was observed with prosthesis (Fig. 8). The improved velopharyngeal closure can be attributed to the effect of prosthesis and speech therapy. This result support the findings of Jian, Ningyi, and Guilan, (2002) who reported improvement in velopharyngeal closure by using a temporary oral prosthesis and speech training.

Conclusions

The velopharyngeal port closure has an effect on the laryngeal airway dynamics and voice quality in an individual with unrepaired submucous cleft palate. The variations in laryngeal parameter were observed with and without prosthesis. The difference was also noticed in vocal loading condition. But the effect was more in subject than compared to controls. However, the results are preliminary in nature and to conclude further studies need to be carried out on the efficacy of using palatal lift prosthesis on laryngeal aerodynamics and voice quality of cleft lip and palate population.

References

Babu, R. M., Rathna, N., & Bettagiri, R. (1972). Test of Articulation in Kannada. *Journal of All India Institute of Speech and Hearing, 3*: 64-67.

Baken, R. J. (1987). *Clinical Measurement of Speech and Voice*. Boston, MA: College-Hill Press.

Benjamin, B. J. (1986). Dimensions of the older female voice. *Language and Communication, 6*: 35–45.

Brustello, C. M. B., Paula, F. A., & Yamashita, (2010). Laryngeal resistance in individuals with marginal velopharyngeal closure. *Journal of the Brazilian Society of Speech, 15(1)*: 63-71.

Gelfer, M. P., Andrews, M. L., & Schmidt, C. P. (1991). Effects of prolonged loud reading on selected measures of vocal function in trained and untrained singers. *Journal of Voice, 5(2)*: 158–167.

Gelfer, M. P., Andrews, M. L., & Schmidt, C. P. (1996). Documenting laryngeal change following prolonged loud reading. *Journal of Voice, 10(4)*: 368–377.

Greene, M. C. L. & Mathieson, L. (1989). *The Voice and Its Disorders*. London: Whurr Publishers.

Grillo, E. U. & Verdolini, K. (2008). Evidence for distinguishing pressed, normal, resonant, and breathy voice qualities by laryngeal resistance and vocal efficiency in vocally trained subjects. *Journal of Voice, 22*: 546-552.

Grillo, E. U., Perta, K & Smith. L. (2009). Laryngeal resistance distinguished pressed, normal, and breathy voice in vocally untrained females. *Logopedics Phoniatrics Vocology, 34 (1)*: 43-48.

Guyette, T. W., Sanchez, A. J & Smith, B.E. (2000). Laryngeal airway resistance in cleft palate children with complete and incomplete velopharyngeal closure. *Cleft Palate – Craniofacial Journal, 37(1):* 61-64.

Heylen, L., Wuyts, F. L., Mertens, F., De Bodt, M., Pattyn, J. & Croux, C. (1998). Evaluation of the vocal performance of children using a voice range profile index. *Journal of Speech Language Hearing Research, 41:* 232–238.

Jian, S., Ningyi, L., & Guilan, S. (2002). Application of obturator to treat velopharyngeal incompetence. *China Medical Journal, 115: 842*–845.

Jilek, C., Marienhagen, J., & Hacki, T. (2004). Vocal stability in functional dysphonic versus healthy voices at different times of voice loading. *Journal of Voice, 18(4)*: 443–453.

Kaplan, H. M. (1960). *Anatomy and Physiology of Speech*. New York: McGraw-Hill.

Kummer, A. W. (2008). Resonance disorders and velopharyngeal dysfunction (VPD). *Cleft palate and craniofacial anomalies-Effects on speech and resonance.* 2nd ed. NewYork: Delmar Cengage.

La Velle, W. E. & Hardy, J. C. (1979). Palatal lift prostheses for treatment of palatopharyngeal incompetence. *Journal of prosthetic dentistry, 42*: 308-315.

Leeper, H., Macrae, D., & Mcknight, M. (1994). Voice production characteristics of cleft palate children. *Presented at the American Cleft Palate/ Craniofacial Association Meeting; May 18-21*, Toronto, Canada.

Lewis, J. R., Andreassen. M. L., Leeper, H. A., Macrae. D. L., & Thomas, J. (1993). Vocal characteristics of children with cleft lip/ palate and associated velopharyngeal incompetence. *Journal of Otolaryngology, 22*: 113–117.

Marsh, J. L. & Wray, R. C. (1980). Speech prosthesis versus pharyngeal flap: a randomized evaluation of the management of VP incompetency. *Plastic and reconstructive surgery, 65*: 592-594.

McWilliams, B. J., Bluestone, C. D., & Musgrave, R. H. (1969). Diagnostic implications of vocal cord nodules in children with cleft palate. *Laryngoscope, 79*: 2072–2084.

Miller, C. J. & Daniloff, R. (1993). Airflow measurements: Theory and utility of findings. *Journal of Voice, **7***: 38–46.

Niebudek-Bogusz, E., Kotylo, P., & Sliwinska-Kowalska, M. (2007). Evaluation of voice acoustic parameters related to the vocal-loading test in professionally active teachers with dysphonia. *International Journal of Occupational Medicine and Environmental Health, 20(1):* 25-30.

Pinto, J. H. N., Dalben, G. D. S., & Pegoraro-Krook, M. I. (2007). Speech intelligibility of patients with cleft lip and palate after placement of speech prosthesis. *Cleft Palate-Craniofacial Journal, 44 (6):* 635-641.

Pushpavathi, M. & Sreedevi, N. (2004). Effect of palatal lift on speech acoustics. *Proceedings of NSA -2004*, 39.

Remacle, A., Finck, C., Roche, A., & Morsomme, D. (2011). Vocal impact of a prolonged reading task at two intensity levels: objective measurements and subjective self-ratings. *Journal of Voice, 26(4):* 177-186.

Robison, J. G. & Otteson, T. D. (2011). Prevalence of hoarseness in the cleft palate population. *Journal of Otolaryngology - Head and Neck Surgery, 137(1):* 74-77.

Seunghee, H. A., Hyunsub, S., Zhi, M., & Kuehn, D. P. (2004). An Acoustic study of the temporal characteristics of nasalization in children with and without cleft palate. *Cleft Palate–Craniofacial Journal,* September, *41(5)*: 535-543.

Stemple, J. C., Stanley, J., & Lee, L. (1995). Objective measures of voice production in normal participants following prolonged voice use. *Journal of Voice, 9(2)*: 127–133.

Tachimura, T. T., Kotani, Y., & Wada, T. (2004). Nasalance scores in wearers of a palatal Lift Prosthesis in Comparison with Normative Data for Japanese. *Cleft Palate Craniofacial Journal, 41(3)*: 315–319.

Titze, I. R., Svec, J. G., & Popolo, P. S. (2003). Vocal dose measures: quantifying accumulated vibration exposure in vocal fold tissues. *Journal of Speech Language, and Hearing Research, 46*: 919-932.

Van Lierde, K. M., Claeys, S., De Bodt, M. & Van Cauwenberge, P. (2004). Voice characteristics in children with cleft palate: A Multiparameter Approach. *Journal of Voice, 18(3)*: 354-362.

Velasco, M. G., Ysunza. A., Hernandez, X., & Marquez, C. (1988). Diagnosis and treatment of submucous cleft palate: a review of 108 cases. *Cleft Palate Journal, 25*:171.Warren, D. (1986). Compensatory speech behaviors in cleft palate: a regulation/ control phenomenon. *Cleft palate journal, 23*: 251-260.

Vilkman, E., Lauri, E. R., Alku, P., Sala, E., & Shivo, M. (1999). Effects of prolonged oral reading on F0, SPL, Subglottal pressure and amplitude characteristics of glottal flow waveforms. *Journal of Voice, 13(2)*: 303-312.

Vintturi, J., Alku, P., Sala, E., Sihvo, M., & Vilkman, E. (2003). Loading-related participative symptoms during a vocal loading test with special reference to gender and some ergonomic factors. *Folia Phoniatrica Logopedics, 55(2)*: 55–69.

Webb, M. A., Starr, C. D., & Moller, K. (1992). Effects of extended speaking on resonance of patients with cleft palate. *Cleft Palate – Craniofacial Journal, 32(1)*: 22-26.

Wilder, C. N. (1984). Normal and disordered speech and voice. In C. N. Wilder and B. E. Weinstein (Eds) *Aging and Communication: Problems in Management*. New York: The Haworth Press: 21–29.

Wuyts, F. L., De Bodt, M. S., Molenberghs, G., Remacle, M., Heylen, L., & Millet, B. (2000). The Dysphonia Severity Index: an objective measure of vocal quality based on a multiparameter approach. *Journal of Speech Language Hearing Research, 43*: 796–809.

Zajac, D. J. & Linville, R. N. (1989). Voice perturbations of children with perceived nasality and hoarseness. *Cleft Palate Journal, 26*: 226-232.

Zajac, D. J. (1995). Laryngeal airway resistance in children with cleft palate and adequate velopharyngeal function. *Cleft Palate – Craniofacial Journal, 32(2)*: 138-144.

EFFECT OF TYPE OF CLEFT AND SPEECH STIMULI ON SPEECH INTELLIGIBILITY IN INDIVIDUALS WITH CLEFT LIP AND PALATE

[1]Gnanavel K. & [2]Pushpavathi M.

Abstract

Speech intelligibility is the match between the intention of the speaker and the perception of the listener. Intelligibility involves a number of factors, including listener and context variables as well as speaker variables. The objective of the present study is to compare the effect of type of stimuli and type of cleft on perceptual rating of speech intelligibility in individuals with cleft lip and palate. The subjects consisted of 20 individuals with cleft lip and palate who were further divided based on the type of cleft [Repaired cleft lip and palate (5), repaired cleft palate (5), repaired submucous cleft palate (5), unrepaired cleft palate (5)]. The stimuli consisted of 10 words and 10 sentences (oral and nasal sentences) loaded with pressure consonants. The subjects were asked to repeat the stimuli after the investigator. The responses were recorded and subjected to perceptual assessment using a five point speech intelligibility rating scale (Roy, 2000). The perceptual evaluation was done by four speech language pathologists. The results revealed no significant difference in Kruskal Wallis test across types of cleft and type of stimuli (for words, H3 = 1.94, P = 0.58 & for sentences, H3 = 3.379, P=0.33). High inter judge reliability was found between four judges at 0.05 levels of significance on Pearson's correlation coefficient. Cronbach's alpha (α) was calculated for words (α =0.836, P < 0.01) and sentences (α =0.819, P, 0.01).These higher alpha values showed higher inter judge reliability (higher internal consistency) among the four judges. Speech intelligibility can be improved by giving speech therapy even after surgery and it is required to eliminate any compensatory articulation productions developed prior to management.

Key words*: Submucous cleft palate, Pressure consonants, Perceptual rating scale.*

Speech Intelligibility (SI) is the ability of the listener to understand speech (Witzel, 1995). It is an important measure of speech disorder and primary goal of therapeutic intervention. It is defined as the ability of the listeners to understand words and sentences in different communication situations (Smith & Nelson, 1985). It has been used as an index of overall speech adequacy by researchers and clinicians (Bernthal & Bankson, 1998; Weiss, Gordon, & Lillywhite, 1987). DeBodt, Hernandez-Diaz and Van De Heying (2002) defined speech intelligibility as a product of a series of interactive processes such as phonation, articulation, resonance, and prosody.

Individuals with structural defects such as cleft lip and/or palate (CL/P) may have significantly reduced speech intelligibility due to hypernasality, audible nasal air emission, and weak oral pressure consonants.Speech intelligibility is determined by individual factors and also by the interaction of these specific factors as they affect intelligibility for an individual (Kumin, 2001). The primary aim of the surgical or therapeutic management of individuals with cleft lip and palate (CLP) is improvement in the speech intelligibility. In spite of surgical repair of the palate, a number of factors such as presence of oral nasal fistulae, hearing impairment, dental abnormalities, misarticulation, velopharyngeal inadequacy and mental retardation may affect speech production and impact intelligibility (Whitehill &Chau, 2004).The perceived speech quality is the main criterion for evaluating the speech outcomes following an intervention procedure.

The perceptual speech assessment is a global measure to judge the presence of nasality or other speech problems. The two most important and frequently used measures of speech intelligibility are scaling procedures and item identification tasks (Kent et al., 1989). Whitehill (2002) reviewed 57 articles on methods of assessing intelligibility in individuals with cleft lip and palate. She reported that the different methods used are global judgement (15.8%), rating scales (47.4%), articulation test (8.8%), transcription tasks (14%), other means (5.3%) and unspecified (8.8%). Among the rating scale procedures, 7 point rating scale (60%) was the most frequently used followed by a 4 point rating scale (20%).She concluded that increasing intelligibility in speech is the primary goal of intervention. A valid and reliable measure is essential for measuring speech intelligibility in individuals with cleft lip and palate.

[1]Junior Research Fellow, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: vel13feb@gmail.com & [2]Professor in Speech Pathology, AIISH, Mysore-06, Email: pushpa19@yahoo.co.in

Spriesterbach, Moll, and Morris (1961) investigated the impact of type of cleft on articulatory performance in 123 children with different types of clefts. Nine children with cleft of the lip only, 83 children with cleft lip and palate, and 29 children with cleft of palate only were studied. In 114 children with cleft palate 89 had surgical or prosthetic management and the remaining 25 had an unrepaired cleft palate. Templin Darley diagnostic test of articulation (Templin &Darley, 1960) was administered to all the subjects. The results showed that children with cleft palate have poorer articulation than those with cleft lip and palate. Children with cleft of the soft palate only had better articulation than those with cleft of the hard and soft palate, and that children with unilateral clefts have better articulation than those with bilateral cleft. The authors concluded that it is necessary to sub classify the individuals with cleft while studying their articulatory skills.

Karling, Larson, Leanderson, and Henningsson (1993) investigated the speech of 84 individuals with complete unilateral cleft lip and palate (UCLP) and 19 individuals with complete repaired cleft lip and palate (BCLP). All the subjects had undergone the primary palate repair. The speech was judged by professional listeners and compared with a control group of 40 age matched normal individuals. The subjects were asked to read 34 sentences and a short story with all the vowels and consonants in Swedish language. Significant difference was not observed in resonance between the unilateral and bilateral cleft group. Also the results indicated that bilateral cleft group had significantly less intelligible speech and required to undergo extensive speech therapy. They concluded that in spite of speech therapy and palatal surgery significant difference was found between cleft group and normal individual group. This may be due to the late palate surgery and late onset of speech therapy in individuals with cleft palate.

Grunwell (1993) studied 80 individuals with a large variety of different types of repaired clefts (Cleft lip and cleft of soft palate, UCLP, BCLP, Post alveolar cleft and Cleft of soft palate only). The subjects were grouped according to the age 2.6 yrs, 5 yrs and 10 yrs old and they were assessed on a standard speech sample. All the subjects were asked to name the 47 items in the item picture naming test. The samples were tape recorded and subsequently transcribed by two judges using narrow phonetic transcription. The inter and intra judge reliability was found to be high between the two judges (84 % level of agreement). The individuals with bilateral and unilateral cleft palate exhibited significantly more errors in their speech than individuals with cleft of soft palate only. As the age increased, there was a reduction in the number of errors in the target phoneme. The author concluded that the difference in the speech errors may be due to the difference in the oral structures associated with these types of cleft.

Van Lierde, Bonte, Baudonck, Van Cauwenberge, and De leenheer (2002) compared the effect of unilateral cleft lip and palate (UCLP) and bilateral (BCLP) on speech intelligibility. They considered 37 individuals with UCLP (19) and BCLP (18). The subjects considered did not have any associated syndromes and undergone same surgical procedure. The stimuli included spontaneous speech sample, reading / repetition of sentences. Perceptual speech judgment was done by 3 speech language pathologists (SLP's) using 4 point nominal rating scale. The results did not show any significant difference across both the groups. Significant differences were found between individuals with cleft palate and normal subjects. The findings of the study indicated that children with BCLP have poorer performances regarding speech intelligibility, nasalance and nasality patterns than children with UCLP.

Whitehill and Chau (2004) studied single word intelligibility in individuals with cleft palate across age, gender and type of cleft. They included 15 Cantonese speaking individuals with cleft lip and palate in the age range of 5-44 years. The subjects were further divided based on the type of cleft in which nine individuals had unilateral cleft lip and palate and six had bilateral cleft lip and palate. The stimuli consisted of 60 words loaded with pressure consonants. Eight Cantonese speaking normal adults served as listeners. The intelligibility was assessed according to the age and type of cleft. The results did not show any significant difference in speech intelligibility across age, gender and type of cleft. They concluded that the presence of intelligibility problems in adults with cleft palate indicates the need for continuation of the speech intervention.

Hodge and Gotzke (2007) evaluated the construct and concurrent validity of speech intelligibility probe in children with cleft palate. The participants considered were five children with cleft palate in the age range of 3.2 to 6.8 years and 10 normal children without any craniofacial abnormalities.

The subjects were asked to imitate the single words and 100 word spontaneous speech samples. The speech sample was recorded and played back to the listeners. The listeners were asked to identify the words in open set and closed set word identification task. The result showed that individuals with cleft palate had lower speech intelligibility scores. A high correlation was found for intelligibility scores of single word intelligibility probe and spontaneous speech sample. They concluded that the single word intelligibility probe is a reliable assessment tool to measure children's speech intelligibility.

The above mentioned studies investigated the type of cleft on different speech parameters such as articulation, resonance and speech intelligibility in individuals with cleft lip and palate. The literature mentioned above provides contradictory results on the effect of cleft type on speech intelligibility. There are very few studies which evaluated the speech intelligibility across different stimuli. The objective of the present study is to investigate the effect of cleft type and the type of speech stimuli (words and sentences) in individuals with cleft lip and palate.

The aims of the present study were to

1) Compare the speech intelligibility across words and sentences in individuals with repaired and unrepaired cleft palate
2) Investigate the effect of type of cleft and speech stimuli on speech intelligibility scores.
3) Study the inter judge reliability across judges for speech stimuli

Method

Participants

Twenty individuals (15 males and 5 females) with cleft lip and palate in the age range of 10-25 years were considered. The participants were further divided based on the status of the palate into repaired (15 no.) and unrepaired cleft palate (5 no.). And depending on the type of cleft, the repaired groups of individuals were further classified under repaired cleft of lip, hard and soft palate (5) repaired cleft palate only (5) and repaired submucous cleft palate (5). All the individuals considered for the study had Kannada as their mother tongue .Individuals with associated problems such as syndromes, nasal pathologies, hearing impairment were excluded from this study. The language abilities of the individuals with cleft lip and palate were normal.

Materials and Procedure

The speech stimuli consisted of 10 words loaded with pressure consonants adopted from Kannada articulation test (Babu ,Rathna & Bettagiri ,1972) and 10 sentences (5 oral and 5 nasal sentences)developed by Jayakumar and Pushpavathi (2005). Participants were asked to repeat the words and sentences after the clinician. The responses were recorded using a digital voice recorder (Olympus WS 550M).The recorded samples were blinded and presented to four speech language pathologist for perceptual judgment.

A five point speech intelligibility rating scale (1-5) adopted from Ray (2000) was used for perceptual judgment. (5) = Fully intelligible speech, (4) <10% not fully intelligible = good intelligibility, (3)10-20% not fully intelligible = limited intelligibility, (2) 20-30% not fully intelligible =poor intelligibility, (1) >30% not fully intelligible = unintelligible speech. Prior to actual rating, 40 min training session was conducted in which 5 samples which were not included in the current study were given to the judges as a practice session. The recorded speech samples were randomized separately for each judge to avoid any order effects.Instructions for rating the samples were provided orally and in written form.

Analysis

The trained listeners rated the randomized samples separately in a quiet room situation. The average mean values were calculated separately for the perceptual judgement for words and sentences for each group of subjects. Inter judge reliability was calculated across trained judges for different speech stimuli.

Statistical Analysis

Statistical computation was done using Statistical Package for the Social Sciences Software version 18. A non-parametric test Kruskal Wallis Test was done to find if there is any significant difference between types of cleft and the stimulus. Paired t test was done to find if there is any significant overall difference across words and sentences for all the subjects. Pearson's correlation co-efficient and Cronbach's alpha (α) was calculated to find the inter-judge reliability across four judges.

Results

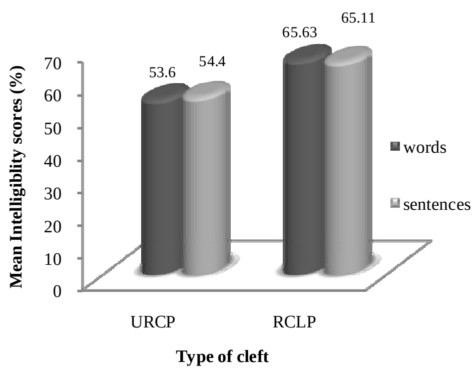
The results obtained from the perceptual judgment by four trained judges are described according to the speech tasks used on different group of subjects. The results of the present study is discussed in the below mentioned sections.

a) **Comparison of speech intelligibility across words and sentences in individuals with repaired and unrepaired cleft palate:** The mean and standard deviation of speech intelligibility percentage scores for both words and sentences across type of cleft is represented in Table1.The mean intelligibility score for repaired submucous cleft group was high for both words (69.2%) and sentences (67.55%) than other repaired cleft types.

Table 1: *Mean and S.D of speech intelligibility ratings for words and sentences across type of cleft*

	Words Mean (S.D)	Sentences Mean (S.D)
RCLP	67.10 (18.79)	65.00 (17.99)
URCP	53.46 (20.17)	54.40 (13.14)
RSCP	69.20 (12.21)	67.55 (8.31)
RCP	60.60 (4.00)	62.80 (5.16)

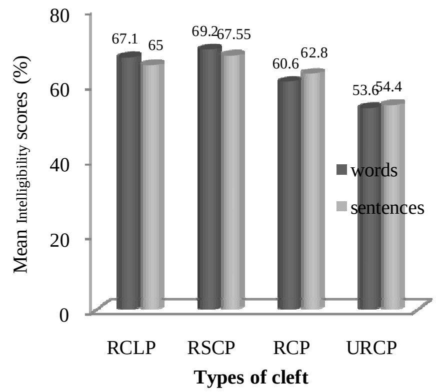
[RCLP – Repaired cleft lip and palate, URCP – Unrepaired cleft palate, RSCP – Repaired submucous cleft palate, RCP – Repaired cleft palate]



[URCP- Unrepaired cleft palate, RCLP- Repaired cleft lip and palate]
Figure 1: *Mean Speech intelligibility scores (%) for words and sentences across individuals with repaired and unrepaired cleft palate.*

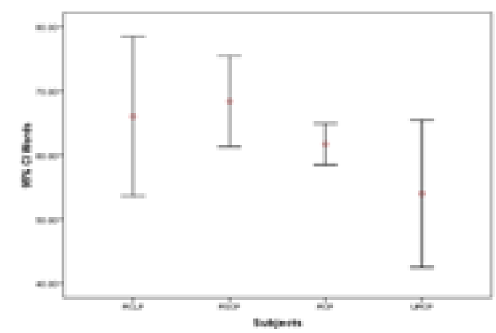
The figure 1 shows mean speech intelligibility (%) scores for repaired and unrepaired cleft palate group for words and sentences. The mean intelligibility scores for repaired group (65%) were higher compared unrepaired group (53%). The significant difference between words and sentences was not seen across the group.

Figure 2 depicts the mean intelligibility scores for different subgroups in individuals with cleft



[RCLP – Repaired Cleft lip and palate, RSCP – Repaired submucous cleft palate, RCP – Repaired cleft palate, URCP – Unrepaired cleft palate]
Figure 2: *Mean Speech intelligibility scores (%) for words and sentences across individuals with repaired and unrepaired cleft palate*

lip and palate. The repaired submucous cleft palate (RSCP) group had higher intelligibility score for words and sentences followed by repaired cleft lip and palate (RCLP), repaired cleft palate only (RCP) group. The lowest speech intelligibility score was obtained by unrepaired cleft palate group for both the stimuli.



[RCLP – Repaired Cleft lip and palate, RSCP – Repaired submucous cleft palate RCP – Repaired cleft palate, URCP – Unrepaired cleft palate]
Figure 3*: Error Bar graph for speech intelligibility scores across subjects*

The error bar graph (figure 3) depicts the standard deviation of the speech intelligibility scores for the different types of cleft. The unrepaired cleft palate group showed grater variability in the intelligibility scores which was followed by repaired cleft lip and palate (RCLP), repaired submucous cleft palate (RSCP). The lesser deviation in the intelligibility score was shown by repaired cleft palate (RCP) group which further shows the higher consistency in the scores obtained by the subjects in that group. The center point in each error bar represents the mean intelligibility score in percentage.

b) **Effect of cleft type and type of stimuli on speech intelligibility scores:** Kruskal Wallis Test was administered to study the effect of type of cleft and type of stimuli (words and sentences) on speech intelligibility scores of individuals with cleft lip and palate. No significant difference was found across types of cleft and type of stimuli on speech intelligibility scores. For both words and sentences the P value was greater than 0.05 levels. Paired t test was done to find difference across words and sentences for all the subjects on speech in speech intelligibility scores. The results showed no significant difference across words and sentences (t_{19}=0.11, P=0.91 > 0.05).

c) **Inter judge reliability across judges for words and sentences:** The reliability was assessed across the four trained judges who had rated the speech samples. Inter judge reliability was also calculated by obtaining the Pearson's correlation co-efficient values and Cronbach's alpha (α) values for both words and sentences. Pearson's correlation co-efficient for words across four judges were calculated and the results showed higher inter judge reliability between all the four judges for words at 0.05 levels. The significance was at 0.0l levels between judges A &B, C&B and A&D. The correlation coefficient values for words were represented below in table 2.

Table 2*: Correlation coefficients for inter judge reliability for words.*

Judges	A	B	C	D
A	1	0.72**	0.54*	0.56**
B	0.72**	1	0.59**	0.46*
C	0.54*	0.596**	1	0.46*
D	0.56**	0.46*	0.46*	1

[**correlation is significant at 0.01 levels, *correlation is significant at 0.05 levels]

Pearson's correlation co-efficient for sentences across four judges were calculated and the results showed higher inter judge reliability between judges A& B and B& C for sentences at 0.05 levels. The significance was at 0.0l levels between judges A &C. There was no significant difference between the judges B & D and C&D. The correlation coefficient values for sentences were represented below in table 3.

Cronbach's alpha (α) is the coefficient of reliability was calculated for words (α =0.836, P < 0.01) and sentences (α =0.819, P < 0.01). These higher alpha values showed higher inter judge reliability that is higher internal consistency among the four judges.

Table 3: *Correlation coefficients for inter judge reliability for sentences*

Judges	A	B	C	D
A	1	0.70**	0.51*	0.59**
B	0.70**	1	0.72**	0.20
C	0.51*	0.72**	1	0.44
D	0.59**	0.20	0.44	1

[**correlation is significant at 0.01 levels, *correlation is significant at 0.05 levels]

Discussion

Assessing speech intelligibility is one of the important aspects in understanding speech in individuals with cleft lip and palate. Few studies (Lohmander-Agerskov, 1998; Spriesterbach et al., 1961; Van Lierde et al, 2002) have investigated the effect of cleft type on speech characteristics such as articulation, nasalance, and nasality. The results indicate that cleft type has an effect on resonance and articulation. Very few studies have evaluated the effect of cleft type on overall speech intelligibility. There are still contradicting results on this issue. Some authors reported correlation between the type of cleft and overall speech intelligibility (Grunwell, 1993; Spriesterbach et al., 1961). While others did not find any correlation between the type of cleft and overall speech intelligibility scores (Haapanen, 1994; Karling et al., 1993; Van Lierde et al., 2002).

The present study was aimed to study the effect of cleft type and type of stimuli on speech intelligibility in individuals with cleft lip and palate. The results did not show any significant difference between all the four groups on overall speech intelligibility. The same pattern was also found for the two different stimuli (words and sentences). The results of the present study are in consonance with the study done by Van Lierde et al. (2002) who evaluated the speech intelligibility on the different types of cleft (UCLP and BCLP). They also did not find a significant difference between the types of cleft on speech intelligibility. The difference may be due to the small number of subjects considered for the study in each group. Significant difference was not seen across the group which may be due to the correction of structural anomaly in these subjects not the correction of functional, obligatory and compensatory errors.

The mean intelligibility scores were higher for repaired submucous cleft palate group followed by repaired palate group compared to the repaired lip and palate and unrepaired group. The higher speech intelligibility score in the submucous cleft palate individuals is due to the extent of nasal air emission and other articulation problems which are less compared to other cleft deformities. The cleft type speech characteristics and other associated problems are reported to be less in SMCP group compared to cleft lip and palate group. There are no studies on speech intelligibility in submucous cleft palate individuals till now. The results of this study support the study done by Spriesterbach et al. (1961) and Grunwell (1993) who reported that the subjects with cleft of soft palate only exhibited fewer errors than individuals with cleft of the hard palate and soft palate.

The speech intelligibility rating scores of the repaired cleft palate group were better than unrepaired cleft palate group. This may be because of the surgical correction which helped in better oral airflow during speech in the repaired group. These findings strengthen the study done by Lohmander-Agerskov (1998) who reported better speech intelligibility in repaired cleft palate group compared to the unrepaired cleft palate group. This may be attributed to the improvement in the articulation and resonance at some extent, after the surgery.

The present study also indicated no significant difference on speech intelligibility across words and sentences for all the subjects. The trained listeners did not perceive any significant difference between the type of cleft and speech stimuli. This finding is contradicting with the previous study by Hodge and Gotzke (2007) in which they studied the correlation of the single word intelligibility probe with the 100 word sample of spontaneous speech. They found high correlation between the single word intelligibility probe test and spontaneous speech sample. This suggests that the spontaneous speech or connected speech is important stimuli when measuring the speech intelligibility in individuals with cleft lip and palate.

A rating scale procedure is only justified if its reliability and validity are proven (Whitehall, 2002). The reliability of the rating procedure in the present study appeared to be very high. The inter judge reliability for all the four judges were high for words and sentences. The internal consistency of the rating done by the trained listeners was high. This result was in consonance with the study by Van Lierde et al. (2008) in which they found higher inter judge reliability for overall intelligibility of speech of CLP before and after the surgical management.

Conclusions

The present study was an attempt to investigate the effect of type of cleft and type of stimuli in individuals with cleft lip and palate. The study revealed that there is no significant difference between the type of cleft and stimuli (words and sentences).The spontaneous speech sample can also be used in the future research for better understanding of speech intelligibility. The results of the current study may need to be interpreted with caution as the sample size was small. Large number of subjects to be involved in each group .Along with the rating scales, phonetic transcription of the speech samples is required.

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References

Babu, R.M., Rathna, N., &Bettagiri, R. (1972). Test of articulation in Kannada. *Journal of AIISH, 3,* 64-79.

Bernthal, J. E., & Bankson, N. W. (1998). *Articulation and phonological disorders*. (4th Ed.). Needham Heights, MA: Allyn & Bacon.

De Bodt, M., Hernandez-Diaz, H., & Van De Heyning, P. (2002). Intelligibility as a linear combination of dimensions in dysarthric speech. *Journal of Communication Disorders, 35,* 283-292.

Grunwell, P. (1993). *Analyzing Cleft Palate Speech*. London, Whurr.

Haapanen, M.L. (1994). Cleft type and speech proficiency. *Folia Phoniatrica et Logopaedica, 46,* 57–63.

Hodge, M., & Gotzke, C.L. (2007). Preliminary results of an intelligibility measure for English-speaking children with cleft palate. *The Cleft Palate-Craniofacial Journal, 44*(2), 163-174.

Karling, J.B., Larson, O., Leanderson, R., & Henningsson, G. (1993) .Speech in unilateral and bilateral cleft palate patients from Stockholm. *Cleft Palate Craniofacial Journal*, *30,* 73–77.

Kent, R.D., Weismer, G., Kent, J.F., &Rosenbek, J.C. (1989). Toward phonetic intelligibility testing in dysarthria. *Journal of Speech and Hearing Disorders, 54*, 482–499.

Kumin, L. (2001).Speech intelligibility in individuals with Down syndrome: A framework for targeting specific factors for assessment and treatment. *DownSyndromeQuarterly, 6,* 1-8.

Jayakumar, T., &Pushpavathi, M. (2005). Normative score for nasometer in Kannada. *Student research at AIISH*, Mysore, Volume III, 44-61.

Lohmander-Agerskov, A. (1998). Speech outcome after cleft palate surgery with the Goteborg regimen including delayed hard palate closure. *Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery, 32,* 63–80.

Ray, J. (2002). Treating phonological disorders in a multilingual child: A case study. *American Journal of Speech Language pathology, 11,* 305-315.

Smith, L., & Nelson, C. (1985). International intelligibility of English: Directions and resources. *World Englishes, 4,* 333–342.

Spriesterbach, D.C., Moll, K.L., &Morris, H.L. (1961).Subject classification and articulation of speakers with cleft palates. *Journal of Speech Hearing Research*, *4*, 362–372.

Templin, M., & Darley, F.L., (1960). Templin –Darley Tests of Articulation. *Bureau of Educational Research and Service*, University of Iowa, Iowa City, Iowa.

Van Lierde, Bonte, K.M., Baudonck, N., Wuyts, F.L., & Van Cauwenberge, P. (2002). Effect of cleft type on overall speech intelligibility and resonance. *Folia Phoniatrica et Logopaedica, 54,* 158-168.

Van Lierde, Bonte, K.M., Baudonck, N., VanCauwenberge, P., & De leenheer, E.M. (2008). Speech outcome regarding overall intelligibility, articulation, resonance and voice in Flemish children a year after pharyngeal flap surgery: A pilot study. *Folia Phoniatrica et Logopaedica, 60*(5), 223-232.

Weiss, C., Gordon, M., & Lillywhite, H. (1987).*Clinical Management of Articulatory and Phonological Disorders,* Baltimore, MD: Williams & Wilkins.

Whitehill, T.L. (2002). Assessing intelligibility in speakers with cleft palate: a critical review of the literature. *Cleft Palate Craniofacial Journal, 39,* 50–58.

Whitehill, L.T., & Chau.C.H. (2004). Single word intelligibility in speakers with repaired cleft lip and palate. *Clinical linguistics &Phonetics, 18,* 4–5, 341–355.

Witzel, M.A. (1995). Communicative impairment associated with clefting. In: Shprintzen RJ, Bardach J, editors. *Cleft palate speech management: A multidisciplinary approach*. Boston: Mosby. , 137-166.

FREQUENCY OF OCCURENCE OF PHONEMES IN KANNADA: A PRELIMINARY STUDY

[1]Sreedevi N., [2]Smitha K. Nair, & [3]Vikas M. D.

Abstract

Kannada is one of the traditional languages among the four Dravidian languages with a fine grammatical tradition. It is an enriched language with complex range of regional, social and stylistic variations. The frequency of occurrence of phoneme data is crucial to understand the language structure and also has wide applications in audiology and speech language pathology. The phoneme frequency is under research since 1930s. Studies on phonemes in various languages like English (Delattre, as cited in Edwards, 2003) Hindi (Ghatage, 1964), Oriya (Kelkar, 1994) were based on written source of materials. The purpose of the present study was to obtain the frequency of occurrence of various phonemes in Kannada using conversation samples. Participants included 21 fluent native speakers of Mysore dialect of Kannada in the age range of 20 to 50 years divided into 5 groups. Conversation sample of each of the five groups were recorded separately for 25-30 minutes. The samples obtained were transcribed using IPA transcription. Inter judge and intra judge reliability of phonetic transcription was evaluated for 10% of the recorded samples. Further it was analyzed using the SALT software for obtaining frequency of phonemes. Mean and standard deviation of frequency of phonemes of all the five samples were obtained. The results show that vowel /a/ was the most frequently occurring phoneme followed by /n/, /I/. /e/, /r/, /a:/, /d/, /l/, /u/, /g/ and /k/ in Kannada. Phonemes /h/, /s/, /p/, /tʃ /, /dʒ/, /ʃ/ were less frequent in conversational samples. Overall, vowels constituted 44.3% and consonants 55.3% of the data. The results obtained will aid audiologists and speech language pathologists in developing and updating the existing test material for evaluating various communication disorders and also for selection of treatment targets in such population. The study has implications in the area of linguistics and speech synthesis tasks also.

Key words*: SALT software, Dravidian languages.*

Phonology is the study of how the speech sounds are organized and the functions of those within the sound system of a particular language. According to Bloomfield (1914), phonology is the organization of sounds into patterns and phonemes are the minimal units of distinctive sound feature. In Webster's third new international (1961), a phoneme is defined as the smallest unit of speech distinguishing one unit from another, in all the variations it displays in the speech of one person or in one dialect as a result of modifying influences such as neighboring sounds or stress. Kruszewski was the first to use the term phoneme in late 1870s.

Most contemporary linguists view phoneme as the minimal bundle of relevant sound features. Trager and Smith (1951) proposed 45 phonemes for English such as /p/, /b/, /t/, /d/, /k/, /g/ etc. The phonemes are distinctive in all the languages but use of phonemes differs. English native speakers can clearly distinguish the phonemes of 'key' and 'caw' whereas the speaker of Hindi will be unlikely to hear any difference between the consonants of 'key' and 'caw', because his language does not force him to establish such a contrast. Kannada is one of the four major literary languages of the Dravidian family, the other three being Telugu, Tamil and Malayalam. It has a fine grammatical tradition and a very complex range of regional, social and stylistic variations: the Mysore/Bangalore dialect, the coastal dialect (Mangalore), the Dharwar dialect and Kalaburgi dialect (Upadhyaya, 1976). The Kannada lexicon has been enriched by uninhibited borrowing from several sources, majorly from Sanskrit, Hindi-Urdu, and English.

Determining frequency of occurrence of phonemes is foundation for linguistics and offers beneficial information to research and clinical fields. The frequency of occurrence of phonemes plays a crucial role in the development of linguistic theory in a number of areas including the grammatical relations, semantic structure etc. Audiologists use speech materials for hearing assessment and also in intervention. Several speech materials they use are in the form of word lists, involving phonetically balanced phonemes in a language. As these are language specific,

[1]Reader in Speech Sciences, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: srij_01@yahoo.co.in, [2] Clinical Linguist, AIISH, Mysore-06, Email: krishnasmi@gmail.com & [3]Research Officer, AIISH, Mysore-06, Email: vikasmdslp@gmail.com

they require most frequently occurring phonemes in that particular language (Egan, 1948; Campbell, 1965).

The frequency of occurrence of phonemes is in research since 1930s. As the phonological structure varies with the language use and the dialects, several studies were carried out in different languages. Delattre (as cited in Edwards, 2003) studied frequency of occurrence of phonemes in English. He considered 2000 syllables taken from different sources like narration and dramatization. Results indicated that most occurred vowels were /ə/, /I/, /æ/ and consonants were /t/, /n/, /r/ and /l/.

Up to 1970s the study of phonemes were mainly concentrating on the written context where the frequencies were mostly calculated from sources like newspapers, journals and scripts of the play. Mines, Hanson and Shoup (1978) used conversation in an interview and database of about 1,03,887 phoneme occurrences were obtained. The frequency of occurrences of phonemes were listed in descending order / a, n, t, i, s, r, l, d, ɛ /. These phonemes accounted for 47% of the total data.

There exist differences in frequency of occurrence of phonemes between written and spoken data. Hence Sandoval, Toledano, de la Torre, Garrote and Guirao (2008) studied and compared the syllabic and phonemic frequency in spoken and written context in Castilian Spanish. The results of the study indicated that /a/ and /e/ were the most occurring phonemes in both spoken and written context. Among consonants /s/ occurred about 8% and 7% in spoken and written context respectively. Followed by /s/ it was /n/ which occurred about 7% both in spoken and written contexts. /l/ and /d/ had similar frequency of occurrences. Sandoval et al., (2008) study indicated that even though there is no much difference in the frequency of occurrence of phonemes or syllables, there are slight variations when compared between two different modes i.e., written and spoken.

On similar lines, initial studies on Indian languages available were by Bhagwat (1961) where he calculated the phonemic and morphemic frequencies in Marathi. He considered this could be a source or database for devising a speed script. Ghatage (1964) calculated the phonemic and morphemic frequencies in Hindi using written source of materials. Results showed that vowels occurred more frequently than consonants. Followed by Hindi, Ghatage (1994) studied phonemic and morphemic frequencies in Malayalam using 1,00,000 words from various written materials. The results indicated vowels /a/ and /I/ were the most occurring phonemes. Among consonants palatal nasal /n/ was most occurring followed by /k/ and /m/ respectively. Kelkar (1994) studied phonemic and morphemic frequencies in Oriya. The sources were similar to that of Ghatage's study. The results indicated that vowel /ə/ was the most occurring followed by /a/ and /I/. /r/, /k/ and /t/ were the most found consonant phonemes.

Frequency of occurrence of phonemes in Kannada was first studied by Ramakrishna (1962). He analyzed the speech sounds in Kannada in the written form. The results revealed that long vowels and aspirated phonemes are used relatively less frequently. Also reported that vowel /a/ is the highest occurring vowel and consonants like /r/, dentals /d/ and /t/ are the highly used consonants in Kannada.

Ranganatha (1982) considered 1,00,000 words from different written sources to calculate the frequency of occurrence of phonemes in Kannada. The results revealed that vowel /a/ was most frequently occurring followed by /I/, /u/, /n/, /d/, /a:/. The least frequently occurring phonemes were /p^h/, /g/, /d̪^{h}/, /k^h/, /t̪^{h}/. The data consisted of 48.6% of vowels and 51.4% of consonants.

In another study on Kannada, Jayaram (1985) carried out a longitudinal study for calculating the frequency of occurrence of phonemes considering written data from many sources like newspapers, journals etc. He listed out a series of vowels and consonants by rank order of their frequency of occurrence and the order was /a, I, n, r, u, d, ɔ, e, t, l/. Among consonants /n/, /r/, /d/ occurred most frequently. And the consonants constituted about 55% of the data.

India being a multicultural and multilinguistic background, there are dearth of studies about the frequency of phonemes in Indian languages. These studies would provide a database for developing speech materials for assessment and selecting treatment targets for various communication disorders, knowledge about the most frequently occurred phonemes can help in targeting those phonemes in therapy for hearing impaired. The phonetically balanced word lists that audiologists use for assessing auditory processing disorders like staggered spondaic words (SSW), for checking speech identification scores (SIS), speech in noise test (SPIN) and speech recognition scores (SRT) in routine audiological evaluations are based on such phoneme frequency information and they are highly language specific. Such information can also help in the development of different aids and devices like text to speech converters for individuals with communication disorders.

The studies on frequency of occurrence of phonemes in Indian languages have considered only written source of materials including the earlier studies in Kannada (Ramakrishna, 1967; Ranganatha (1982); Jayaram, 1985). Also these results may not be appropriate at present as there are a lot of new words, modified and borrowed words used in day to day conversation. Also study by Sandoval et al (2008) indicated that there exist differences in phoneme frequency among spoken and written source of data. Hence the present study was planned to obtain the frequency of occurrence of phonemes in conversational speech samples in Kannada.

Method

Participants: Adult fluent native speakers of Kannada in the age range of 20 to 50 years with a minimum of 10 to 12 years of education in Kannada medium were selected for the study. All the participants were native speakers of Mysore dialect of Kannada and resided in Mysore city. Participants did not have any clinical history of speech, language, hearing or any neurological problems. A group of 3 to 5 participants were involved in each recording session. Table 1 shows participant details for each recording session.

Table 1*: Indicates number of participants involved in each recording session*

Recording Sessions	1	2	3	4	5
No. of Participants	4 (2 Males and 2 Females)	5 (4 Males and 1 Female)	4 (3 Males and 1 Female)	4 (1 Male and 3 Females)	4 (2 Males and 2 Females)

Instrumentation: A digital recorder (Olympus WS 100) was used for recording the conversation samples.

Procedure: The data was collected through conversation in controlled natural environments which lasted for about 25 to 30 minutes of duration. All the participants were made to sit comfortably facing each other and familiarize with the other participants of the session. The digital recorder was kept at equidistance from all the speakers. Participants were not given any particular topic about the conversation to avoid the repetition of words. Any current topic of interest was initiated by the participants themselves and conversations were carried out for approximately half an hour. The participants were instructed to avoid words from other languages to the extent possible and to speak only in Kannada as naturally as possible. They were not restricted from using commonly used borrowed English words (E.g.: Bus, ticket, phone, car etc). A total of 5 sessions of general conversation were recorded for the study. Each recording session had different participants engaged in different topics of conversation. Table 2 shows the details of the topic of conversation in each recording session.

Table 2: *Indicates the topic of conversation in each recording session*

Recording Sessions	1	2	3	4	5
Topic of Conversation	Current Education system and political issues.	Family issues, corruption, present government	Casual talk on garments, provisions, postal dept and government officials.	Various cultural and therapeutic programs in Mysore city	Legal issues, family values and studies abroad

Data Analysis: The conversation samples were transcribed using IPA transcription. The repetitive words (eg: I may go to go to bank) and exclamatory remarks were not included in the analysis. English words that are very commonly used (eg. bus, car, bat, ticket etc) in day to day conversation were considered in the analysis.

The raw data obtained was analyzed using the software SALT RV version 9 for the frequency count. SALT (Systematic Analysis of Language Transcripts), is a computer based program designed to help in analyzing and interpreting language samples from one or more speakers during a communicative interaction. It can be used to analyze samples from everyday speech like conversation and narration. Using SALT program, clinicians and researchers can analyze lexical, syntactic, semantic, pragmatic, rate and fluency categories and transcribe samples in a common format. This software analyses the transcribed sample for different parameters such as MLU (Mean Length of Utterance), NDW

(Number of Different Words), TTR (Type Token Ratio) etc. It also gives information about the frequency of words, morphemes, grammatical categories, etc.

Using SALT, an individual's language sample may also be compared to a reference database of language measures. It helps in managing the steps of word count, phoneme count, which can be preloaded with the editable database. So a database of Kannada phonemes was prepared and saved in the editable standard wordlists of SALT software. The database consisted of all the phonemes available in Kannada adapted from Sridhar (1990) which was then modified according to SALT conventions. The whole conversation data is edited with spacing after every phoneme and this edited file is loaded into SALT. The Salt software compares the loaded phoneme file with the database and provides the phoneme count.

Inter-judge and Intra Judge Reliability: Sample of each conversation recording was subjected to inter judge and intra judge reliability measures. Three judges including two post graduate speech language pathologists and a clinical linguist served as judges for determining inter judge reliability measures. Judges were instructed about the phonetic coding procedure and the material to be transcribed before the actual transcription procedure. For inter judge reliability 10% sample of the 30 minutes recording of each sample was transcribed by each of the three judges. The recorded samples were played to the judges independently. They were not allowed to discuss about the transcription of the sample before or after the task. For intra judge reliability 10% of each of the 5 recordings were transcribed and analyzed by one of the authors (a speech language pathologist) after transcribing all the samples completely once. As each individual participant was given equal opportunity in the conversation recording, inter and intra judge reliability was measured for each participant rather than for each recording. The statistical procedure, Cronbach alpha test was used and a reliability index (alpha) of 0.87 was obtained for inter judge and 0.94 was obtained for intra judge reliability.

Results

The present study aimed to obtain the frequency of occurrence of phonemes in conversational speech in Mysore dialect of Kannada. The results of phoneme count obtained from SALT software were tabulated.

A total of 69,624 phoneme counts accounted the data collected from conversation samples of five groups of participants. Figure 1 represents the number of phonemes obtained from the each of the five recording sessions. Out of the five recordings, recording 1 (R1) had the maximum number of phonemes and Recording 2 (R2) had the minimum number of phonemes.

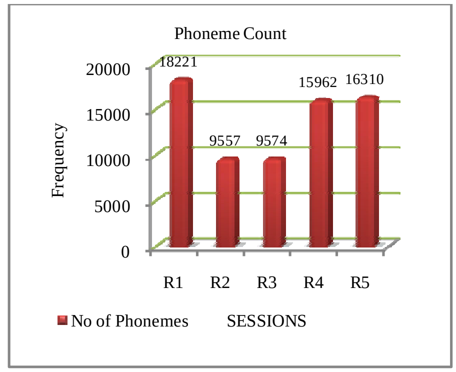

Figure 1*: Shows the total number of phonemes obtained in five conversation samples. R1-R5 indicates five recording sessions.*

Using descriptive statistics, the mean and standard deviations of the frequency of occurrence of vowels and consonants were calculated. Figure 2 represents the mean frequency of vowels and consonants calculated from all the 5 samples. The total vowel count was 30,946 which constituted 44.3% of the total data whereas consonants accounted for 38,618 which is 55.3% of the total data.

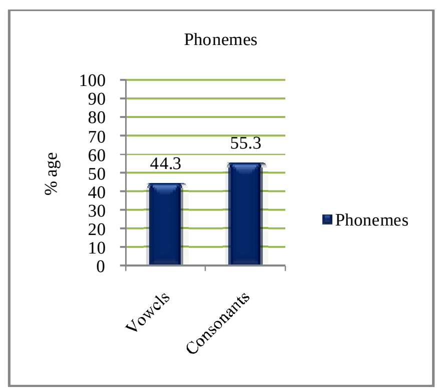

Figure 2: *Mean frequency of occurrence of vowels and consonants in percentage.*

Table 3 shows frequency of occurrence of the most frequently occurring phonemes along with their percentage of occurrence in each of the five recordings. From recording session 1 (R1) total number of 3671 words were obtained which consisted of 18,221 phonemes. The most frequently occurred phoneme was /a/ (2819) followed by consonant /n/ (1563). The frequency of occurrence of other phonemes in decreasing order are /I/, /r/, /e/, /d/, /t/, /l/, /u/, /k/ and /g/. From recording session 2 (R2) 1860 words were obtained which consisted of 9,557 phonemes. The frequency of occurrence followed a similar trend as of R1 as vowel /a/ (1313) was followed by consonant /n/ (710). The frequency of occurrence of other phonemes in decreasing order are: /a/, /n/, /I/, /e/, /r/, /a:/, /d/, /l/, /u/, /t/, /k/ and /g/.

A total number of 2,153 words were obtained from recording session 3 (R3) which consisted of 9,574 phonemes. The frequency count obtained were similar to first two recording sessions with /a/ (1289) being most frequently occurred phoneme followed by /n/ (765). The frequency of occurrence of other phonemes in decreasing order are: /I/, /e/, /d/, /r/, /a:/, /l/, /t/, /u/, /k/ and /g/.

Table 3*: Shows the frequency and percentage (in parenthesis) of occurrence of the most frequently occurring phonemes for each recording session*

	/a/	/n/	/I/	/e/	/r/	/a:/	/d/	/l/	/t/	/u/
R 1	2819	1563	1246	1090	1094	1065	1013	847	889	767
	(15.4)	(8.5)	(6.8)	(5.9)	(6)	(5.8)	(5.5)	(4.6)	(4.8)	(4.2)
R 2	1313	710	688	592	542	502	490	522	352	381
	(13.7)	(7.4)	(7.2)	(6.1)	(5.6)	(5.2)	(5.1)	(5.4)	(3.6)	(3.9)
R 3	1289	765	677	582	527	500	527	478	431	395
	(13.4)	(7.9)	(7)	(6)	(5.5)	(5.2)	(5.5)	(4.9)	(4.5)	(4.1)
R 4	2196	1214	1147	909	813	823	882	929	806	717
	(13.7)	(7.6)	(7.1)	(5.6)	(5)	(5.1)	(5.5)	(5.8)	(5)	(4.4)
R 5	2264	1264	1158	936	794	863	836	778	687	883
	(13.8)	(7.7)	(7.1)	(5.7)	(4.8)	(5.2)	(5.1)	(4.7)	(4.2)	(5.4)

A total number of 1860 words were obtained from the recording session 4 (R4) which included 9,557 phonemes. The trend remained same with /a/ (2196) being most frequently occurred phoneme followed by /n/ (1214). The frequency of occurrence of other phonemes in decreasing order are: /I/, /l/, /e/, /d/, /a:/, /r/, /t/, /u/, /g/ and /k/.

A total number of 3671 words were obtained from recording session 5 (R5) which consisted of 18,221 phonemes. Same as in the previous four recordings, the most frequently occurred phoneme was /a/ (2264) followed by /n/ (1260). Other frequently occurring phonemes in decreasing order are: /I/, /e/, /u/, /a:/, /d/, /r/, /l/, /t/, /g/ and /k/.

Table 4 provides the mean percentage and standard deviation of all the phonemes from the 5 conversation samples. The standard deviation of the data was minimal, across the sessions and hence the reliability of frequency of phonemes is high.

Table 4: *Shows mean percentage and standard deviation of vowels and consonants*

VOWELS		CONSONANTS			
	Mean % (SD)		Mean % (SD)		Mean % (SD)
/a/	14.06 (0.8)	/n/	7.87 (0.4)	/s/	1.72 (0.2)
/I/	7.08 (0.14)	/r/	5.43 (0.4)	/ʈ/	1.61 (0.38)
/e/	5.94 (0.21)	/l/	5.14 (0.4)	/ɭ/	1.29 (0.28)
/a:/	5.35 (0.27)	/t/	4.47 (0.5)	/j/	1.21 (0.14)
/o/	2.08 (0.24)	/g/	3.46 (0.1)	/p/	0.94 (0.25)
/e:/	1.83 (0.73)	/k/	3.34 (0.1)	/ʃ/	0.61 (0.31)
/o:/	1.26 (0.21)	/m/	2.81 (0.2)	/dʒ/	0.44 (0.12)
/i:/	0.95 (0.27)	/v/	2.59 (0.1)	/tʃ/	0.36 (0.11)
/u:/	0.57 (0.1)	/ɖ/	2.41 (0.3)	/ɳ/	0.27 (0.05)
/ ə/	0.56 (0.88)	/b/	2 (0.2)	/k^h/, /$ʈ^h$/	0.03 (0.02)
		/h/	1.87 (0.4)	/ŋ/, /p^h/, /$ɖ^h$/	0

Figure 3 represents the mean percentage of the most frequently occurring twelve phonemes. On overall observation the frequency of occurrence of phonemes in decreasing order are: /a/, /n/, /I/, /e/, /r/, /a:/, /d/, /l/, /t/, /u/, /g/ and /k/. The consonants /m/ and /v/ occurred for 2.7% of the total data. Vowel /o/ occurred 2% whereas phonemes /h/, /s/, /j/ occurred less than 2% and /p/, /tʃ/, /ʃ/, /i:/, /o:/ occurred less than 1% each of the total data. Consonants /ŋ/, /p^h/, /$ɖ^h$/ did not occur in the five recorded conversational samples though they are present in the Kannada phoneme system. The aspirated phonemes were amply seen. Diphthongs /ai/ and /au/ occurred for less than 1% of the total data. /ai/ occurred for 0.2% and /au/ occurred 0.06% of the total data.

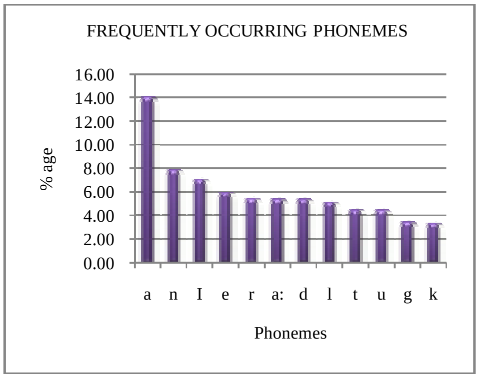

Figure 3: *Mean percentage of frequency of occurrence of frequently occurring phonemes.*

Discussion

The results of the present study had several salient findings. The results indicated that the Kannada conversational speech consists 55.3% of consonants and 44.3% of vowels. This suggests that the consonants are used more than vowels in our day to day conversation. This is in consonance with the earlier reports of several languages. Yegerlehner and Voegelin (1957) observed similar findings in five out of nine languages. The results of Delattre's (as cited in Edwards, 2003) study in English and Jayaram (1985) in Kannada also showed that the consonants are used more than vowels.

In the present study, the most frequently occurring phonemes in descending order are /a/, /n/, /I/, /l/, /e/, /d/, /a:/, /r/, /t/, /u/, /g/ and /k/. These phonemes constituted 70.2% of the total data where as in English it was 47% of the total data (Mines, Hanson & Shoup, 1978). The order of the frequently occurring phonemes in the present study is in contrary to the reports of Ramakrishna (1967) in written Kannada. Though he found that vowel /a/ occurred most frequently, the predominantly occurring consonants were /r/, /d/ and /t/.

In the present study the frequent consonants /n/, /l/, /r/, /t/, /g/ and /k/ constitute 31% of the 55% total consonantal data. /n/ was found to be the most occurring consonant which constituted 7.9% of the total data. The findings of Jayaram (1985) in written Kannada also showed /n/ as the most frequently occuring consonant but was followed by /r/, /d/, /t/ and /l/ indicating a difference in the sequence of the frequently occurring phonemes across these two studies. In English, the results of Sandoval et al (2008) showed that /**s**/ was the most frequently occurred consonant whereas Delattre reported it to be /**t**/ as the mostly frequently occurring consonant. The results of these studies clearly indicate that the frequency of use of consonants varies across languages and also across modes that is written and spoken context.

The aspirated consonants were rarely seen in the present study. Aspirated /p^h/, /ɖ^h/, /k^h/, /ʈ^h/ occurred for 0-0.05% of the total data. This is a significant finding of the present study as the other studies by Ramakrishna (1968), Ranganatha (1982), Jayaram (1985) showed the occurrence (0.5 % to 1.35%) of these aspirated consonants in written context. This indicates that although the aspiration is present in Kannada phoneme system, it is sparingly used in conversation.

Considering the vowels in the present study, vowel /a/ was the most frequently occurring vowel followed by /I/, /e/, /a:/ and /u/. A similar trend was observed by Mines, Hanson and Shoup (1978) in English. However, the order was relatively different in the study by Ranganatha (1982) in written Kannada which showed that /a/ was the most frequently occurring vowel followed by /I/, /u/, /a:/ and /e/.

The present study yielded similar order of phonemes in all the five recordings, i.e. vowel /a/ was the most frequently occurring phoneme followed by nasal /n/ and the relatively less occurring consonants were velars /k/ and /g/. This indicates that there was a consistency in the occurrence of phonemes in spite of the change in the topic of conversations across the different recording sessions. However this needs to be demonstrated on a larger sample of conversation recordings.

Conclusions

The frequency of occurrence of different phonemes in Kannada was determined using conversational samples and the most frequently occurring phonemes in the descending order are /a/, /n/, /I/, /l/, /e/, /d/, /a:/, /r/, /t/, /u/, /g/ and /k/ whch constituted 70.2% of the total data. The less frequently occurring phonemes were /m/, /v/, /o/, s/, /p/, /h/, /tʃ/, /dʒ/, /ʃ/, /i:/ and /o:/. The information obtained in this study is applicable not only in the diagnostic and therapeutic aspects of communication disorders but also in the area of linguistics and speech synthesis which are a few to mention.

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References

Bhagwat, S. V. (1961). Phonemic frequencies in Marathi and their relation to devising a speed-script. Pune: Deccan College

Bloomfield, L. (1914). *Introduction to the study of Language*. New York: Henry Holt.

Campbell, R. A. (1965). Discrimination and word test difficulty. *Journal of Speech and Hearing Research, 8*, 13–22.

Edwards, H. T. (2003). *Applied Phonetics: The sounds of American English (3rd edition).* Canada: Delmar Learning.

Egan, J. P. (1948). Articulation testing methods. *Laryngoscope, 58,* 955–991.

Ghatage, A. M. (1964). *Phonemic and Morphemic frequencies in Hindi*. Poona: Deccan College Postgraduate and Research Institute.

Ghatage, A. M. (1994). *Phonemic and morphemic frequencies in Malayalam*. Mysore: Central Institute of Indian Languages.

Jayaram, M. (1985). Sound and Syllable distribution in written Kannada and their application to Speech and Hearing. *Journal of All India Institute of Speech and Hearing, 16,* 19-30.

Kelkar, A. R. (1994). *Phonemic and Morphophonemic frequency in Oriya*. Mysore: CIIL.

Mines, M. A., Hanson, B. F., & Shoup, J. E. (1978). Frequency of occurrence of phonemes in conversational English. *Language and Speech, 21*, 221-41.

Ramakrishna, B. S. (1962). *Some aspects of the relative efficiencies of Indian languages: a study from information theory point of view.* Bangalore: Indian Institute of Science.

Ranganatha, M. R. (1982). *Morphophonemic analysis of the Kannada language*. Mysore: CIIL.

Sandoval, A. M., Toledano, D. T., de la Torre, R., Garrote, M., & Guirao, J. M. (2008). Developing a Phonemic and Syllabic Frequency Inventory for spontaneous spoken Castalian Spanish and their comparison to Text-based Inventories. *Proceedings of the Language Resources and Evaluation Conference.* Available at: www.lrec-conf.org/proceedings/lrec2008/pdf/283_paper.pdf (accessed: 14 March 2012).

Sridhar, S. N. (2007). *Modern Kannada Grammar*. New Delhi: Manohar.

Trager, G. L., & Smith, H. L. (1951). *An outline of English structure* (Studies in Linguistics, occasional papers, No. 3). Norman, OK: Battenberg Press.

Upadhyaya, U. P. (1976). *A Comparative Study of Kannada Dialects: Bellary, Gulbarga, Kumar, and Nanjangud Dialects.* Mysore: Prasaranga, University of Mysore.

Webster, N., & Gove, P. B. (1961). *Webster’s third new International dictionary of the English language.* London: G. Bell.

INFLUENCE OF 'LISTENING COMPETENCE' ON THE 'SPEECH INTELLIGIBILITY' ASSESSMENT OF PERSONS WITH DYSARTHRIA

[1]Hijas Mohamed, [2]Mahesh B.V. M. & [3]Manjula R.

Abstract

Various factors such as listeners' familiarity & experience with disordered speech, listener's comprehension, ability to predict and the cues provided by the context are considered to be crucial in the the assessment of speech intelligibility in persons with dysarthria. This study addressed the issue of listening competency in normal hearing listeners and its effects on predictability of target words embedded in sentences in naturally degraded speech samples of persons with dysarthria & artificially degraded sample (where distortion was added to the speech of a model speaker). In Experiment 1, thirty normal hearing adults rated the 38 High predictable (HP) and 38 Low predictable (LP) sentences in non degraded and artificially degraded conditions of stimuli produced by a 'model speaker'. In Experiment 2, normal hearing adults rated the intelligibility of the naturally degraded speech samples of 3 persons with dysarthria. Experiment 1 revealed that the mean scores of HP sentences were better & statistically significant compared to LP sentences and the overall combined mean scores of non degraded and artificially degraded stimuli of HP sentences were better compared to the LP sentences. Experiment 2 revealed that the mean scores of HP and LP sentences produced by persons with dysarthria was significantly different. The scores in the HP context of the 'model speaker' (degraded condition) was similar to HP score of the first and third sample of the persons with dysarthria. The LP sentence of the 'model speaker' was similar to the LP score of the third sample of the person with dysarthria. The listening competence amongst the listeners varied across degraded and non degraded HP and LP sentence contexts and the degraded LP sentences were sensitive in evaluating the listening competence of normal listeners' as it was devoid of all the contextual cues for the assessment of speech intelligibility, rendering the task difficult, thus having good potential in tapping the listeners competence.

Keywords*:* *Speech Intelligibility, Listening Competence, Predictability, Dysarthria*

Speech Intelligibility' is defined as "the degree to which a speaker's message can be recovered by a listener" (Kent, Weismer, Kent & Rosenbek, 1989). Assessment of speech intelligibility is a dyadic phenomenon because it assesses for listener's ability to understand the spoken messages that are produced by a speaker. Speech intelligibility is reduced in individuals with dysarthria, as a result of which their ability to convey the messages accurately is compromised (Yorkston, Beukelmen, Strand & Bell, 1999; Duffy, 2005).

Different measures including objective and subjective methods have been used to quantify speech intelligibility in persons with dysarthria. The subjective measures incorporate qualitative judgment of the speech sample of clients with dysarthria by the listeners. But these subjective measures are reported to have poor validity and reliability (Schiavetti, 1992). As an alternative to subjective measures, objective measures have been used where the listener transcribes the target words produced by the persons with dysarthria.

Many factors including signal or speaker variables and listener dependent variables influence the assessment of speech intelligibility by the listeners. Studies have shown that the accurate recognition of words produced by speakers depends on test items and elicitation procedures (Weismer, Jeng, Laures, Kent & Kent, 2001); speaker variables (Dagenis, Watts, Turnage & Kennedy, 1999) listening situation (Barkmeier, Jordan, Robin & Schum, 1991; Hustad & Cahill, 2003; Hustad, 2006); message length (Yorkston & Beukelmen, 1981), contextual cues (Hunter, Pring and Martin, 1991) and listener characteristics like age, experience, familiarity, and comprehension (Yorkston & Beukelmen, 1983; Tjaden & Liss, 1995a; Dagenis, Watts, Tarnage & Kennedy, 1999; King & Gallegos-Santillan, 1999).

Few studies have addressed the personal attributes of listeners who rate the speech intelligibility. Lindblom (1990a, 1990b) suggested that some of the listener dependent variables like experience, context, expectation and familiarity play a crucial role in the

[1]Student, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: hijasmohamedn@gmail.com, [2]Junior Research Fellow, AIISH, Mysore-06, Email: maheshslp@gmail.com & [3]Professor in Speech Pathology, AIISH, Mysore-06, Email: rmanjula08@gmail.com

understanding of a spoken message. A null relationship between familiarization and sentence transcription was evident when listeners were provided with varying periods of exposure to the speech of the persons with dysarthria (Yorkston & Beukelman, 1983; Garcia & Cannito, 1996). In contrast to this observation, Tjaden and Liss (1995a) found good agreement between period of speech familiarization training and sentence transcription in listeners.

Another factor of interest in the assessment of speech intelligibility is that of listener's comprehension of spoken messages. The method of assigning speech intelligibility ratings based on transcribed samples is questioned as to its adequacy in assessing the actual deficits in the spoken language. An alternative approach is to assess the listener's comprehension. Listening comprehension is defined as the extent to which a listener understands the intended messages spoken by a person with dysarthria (Weismer & Martin, 1992). Listening comprehension is evaluated for listener's ability to answer questions related to the content of a message (Drager & Reichle, 2001) or by asking the listeners' to summarize the content of a narrative passage (Higginbotham, Drazek, Kowarsky, Scally & Segal, 1994). Beukelman and Yorkston (1979) studied the relationship between "information transfer" (comprehension) and speech intelligibility of nine speakers with varying severity of dysarthria. The listeners had to complete two tasks, one in which they had to transcribe a paragraph and in another, they had to answer questions after comprehending the content of the paragraph produced by a group of speakers with dysarthria. Significant positive relationship was observed between "information transfer" and intelligibility. However, the results could not be generalized since both the variables were correlated with severity. A similar study by Hustad and Beukelman (2002), found a non significant relationship between speech intelligibility and comprehension when a sample of four persons with severe dysarthria was used. Another important variable in the assessment of speech intelligibility is the influence of distortion in the speech signal on listening. Many of these reports come from studies in the area of speech synthesis wherein a synthesized degraded speech and the speech of person with dysarthria are considered to be similar because both are: (a) not natural, & (b) are acoustically degraded in nature. Comprehension of stimuli in synthesized speech tokens is difficult because of the absence of speaker or cross-speaker reference, segment realization and variability in word environment (Eisenberg, Shannon, Martinez, Wygonski & Boothroyd, 2000).

Many studies have cited variables such as familiarity, experience and context as being crucial in determining the listeners' rating of speech intelligibility of persons with dysarthria (Yorkston & Beukelmen, 1983; Tjaden & Liss, 1995a; Dagenis, Watts, Tarnage & Kennedy, 1999; King & Gallegos-Santillan, 1999). Most of these studies, however, have not addressed the issue of *listening competence* of listener. 'Listening competence' is presumed to be the same across all participants who are 'normal' while measuring speech intelligibility which is not necessarily true. Listening competence has a bearing on the allocation of cognitive resources in the individual, which in turn reflects on how exactly they rate the intelligibility of a spoken message. Few studies have suggested a wide variability within normal listeners with respect to speech intelligibility rating of distorted speech signal (Eisenberg, Shannon, Martinez, Wygonski & Boothroyd, 2000) and recognition of voices after voice identification training (Nygaard & Pisoni, 1998). A similar trend can be expected in normal listeners when they evaluate the speech intelligibility of persons with dysarthria, since their speech is distorted as a factor of the disorder in question. The present study is an attempt to understand the influence of *listening competence* of normal listeners on the rating of speech intelligibility of persons with dysarthria.

Need for the study

Studies on the assessment of speech intelligibility of persons with dysarthria have focused on listener dependent variables such as listeners' familiarity with disordered speech, work experience, contextual information that is associated with the spoken message and listener's comprehension of the spoken message (Beukelman & Yorkston, 1979; Higginbotham et al., 1994; Nygaard & Pisoni, 1998; Eisenberg et. al., 2000; Drager & Reichle, 2001). The issue of variability within listeners with respect to their listening competence is not addressed. The influence of listening competence in assessing the speech intelligibility of degraded speech samples of normal individuals has not been explored. Although, there are very few studies which have addressed the influence of contextual environment of stimuli words on the rating of speech intelligibility (Miller, Hiese & Lichten, 1977; Yorkston & Beukelman, 1981, 1983) only few have looked into the factor of predictability of occurrence of a given word in a linguistic context, the effect of frequency of occurrence of a given word in the language and other linguistic variables (Kalikow, Stevens & Elliott, 1977). The present study attempts to analyze the performance of normal listeners in speech identification task involving ‘high predictable’ and ‘low predictable’ words in sentential context of non degraded and degraded situation and comparison of the same with the scores of intelligibility of the speech of persons with dysarthria. The specific questions raised is with respect to the competence of the listeners in decoding the high and low predictable words presented in sentence context (degraded and non degraded) and its influence over the rating of naturally degraded speech like that of persons with dysarthria.

Aims of the study: The study aimed to analyze and compare the listening competence of normal listeners as reflected in the assessment of speech intelligibility of stimuli consisting of High and Low predictable words spoken by a ‘model speaker’ in a sentential context that is presented in non degraded and degraded conditions with the performance of listeners’ in the assessment of speech intelligibility of naturally degraded speech produced by persons with moderate to severe dysarthria.

Method

Participants

Two groups of participants and a model speaker (M) were included in the experiment

Group I: Listeners

A total of 30 normal adults constituted the listeners group. Of this, twenty two were males and eight were females in the age range of 17-25 years (mean age of 20.16). All the participants had studied in an English medium educational set up for a minimum of 10 years. They were screened for any type of hearing impairment, speech and language problems. It was also ensured that none of the participants were formally trained / had participated in the analysis of speech samples of any type. No attempt was made to balance the gender of the listeners since it was not a variable of interest in the study.

Group II: Speakers with Dysarthria

To select participants only with moderate degree of dysarthria, a narration sample on daily routine was recorded consisting of a minimum of hundred words from 5 persons with dysarthria. The recorded samples were analyzed by the investigators for Percentage Consonant Correct (PCC) (Shriberg & Kwiatowski, 1982). Only those individuals with a PCC score of <65%, suggesting a moderate to severe speech problem were included in the study. Based on the criteria set for PCC, three speakers with moderate degree of dysarthria were included in the age range of 15-55 years (mean age of 33 years). Of these, two were males and one was a female. The presence of receptive & expressive language deficits in the participants was ruled out by administering Western Aphasia Battery (Kertesz, 1982) and also by clinical examination.

Model speaker

A 22 year old male was selected as a ‘model speaker’ in the study. The stimuli (sentences with embedded stimuli words of high and low predictability) were spoken by the model speaker.

Material

Construction of the test sentences

The speech stimuli used in the experiment consisted of 38 High Predictable (HP) and 38 Low Predictable (LP) words (refer Appendix I) embedded in sentences which were adapted from Speech in Noise Perception Test (SPIN), (Kalikow & Elliot, 1977). In the HP sentence type, the final words in the sentence were highly predictable based on the context of the preceding words of the sentence (e.g., My T.V. has a twelve-inch *screen)*. In the LP sentence type, the final words in the sentence were least predictable based on the context of the preceding words of the sentence (e.g., Peter should speak about the *mugs*). Since the original test stimuli in SPIN test had target words in the final position of the sentence which were appropriate to western population, modifications were done by replacing the target words at the end of the sentences of SPIN test with words which were found to be suitable for the Indian population in a pilot study.

Pilot study

A pilot study was carried out to modify the target words to suit the Indian population. Seventy Six (76) sentences (38 each for HP words and LP words in the end) were formed taking care that the sentences were applicable to Indian context, but the last word of the sentence was kept blank. Three judges (post graduates in Speech-Language Pathology) who were proficient in English Language were selected. These judges were instructed to fill in the blanks with the most appropriate words. Later, the target words provided by the three judges were examined by the investigators and the most appropriate words that suited the Indian context were chosen for the final recording.

Procedure

Experiment 1: *Recording Speech Stimuli*

The model male speaker was asked to read the selected target sentences (76 sentences with 38 HP and 38 LP sentences). He was instructed to read the sentences as naturally as possible with natural/habitual, prosody, loudness and pitch. The recording was carried out in a sound treated room using a professional digital sound recorder. The model speaker read out the HP sentences followed by the LP sentences. An interval of 4 seconds was maintained between each sentence and a time gap of 5 minutes was provided between the recordings of HP and LP sentences. The 76 recorded sentences were utilized to create two sets of sentences (with two conditions of HP and LP in each set) as follows:

Set 1 consisted of 76 sentences (38 HP target words at the end and 38 LP target words at the end). The set 1 sentences were used in the experiment as a non distorted set.

Set 2 consisted of 76 sentences (38 HP target words at the end and 38 LP target words at the end) but were subjected to distortion (only on the HP and LP target words). The distortions on the target words in Set 2 were created by superimposing 1 dB white noise on the HP and LP target words at the end of sentences, using *Cool Edit Program (Styrillium Co. Inc., 1999*). The words in the rest of the sentence (other than the terminally placed HP and LP words) were not subjected to any distortion.

In total, set 1 consisted of 38 non degraded HP sentences (NDHP) and 38 non degraded LP sentences (NDLP), set 2 consisted of 38 HP degraded sentences (DHP) and 38 LP degraded sentences (DLP). The stimuli in the experiment 1, thus included 152 token sentences [38 HP + 38 LP in Set 1(non degraded) and 38 HP + 38 LP in Set 2 (degraded)].

Listening task 1

Group 1 participants who served as listeners were presented with 152 token sentences (randomized across degraded and non degraded condition and across HP and LP conditions). The participants were comfortably seated in a room with no distraction. The stimuli were delivered through headphone via digital sound recorder at comfortable loudness level to each of the listener. The listeners were instructed to listen to the sentences which were played through the digital sound recorder and identify the last word in each sentence and write them on a response sheet as heard by them. The sentences were played only once. A time gap of 15 seconds was provided between the sentences to facilitate entry of responses by the listeners on the response sheet. A gap of 5 minutes was provided four times in between the entire experiment to reduce fatigue in the participants.

Experiment 2: *Recording Speech Stimuli from Group 2 participants (Persons with dysarthria)*

In the Experiment 2, three individuals with moderate to severe dysarthria from Group 2 were asked to read out the list of 76 sentences of set 1 (with HP and LP words in the terminal position) one by one in natural and clear manner. Since the presence of dysarthria by itself gave rise to a 'degraded like' speech signal, the speech samples were not subject to superimposition of noise as in experiment 1. It was assumed that the set 2 stimuli of experiment 1 (degraded HP and LP condition) would be equivalent to speech stimuli recorded from persons with dysarthria. Hence in experiment 2, only two conditions (DHP) and (DLP) existed. Like in experiment 1, the speech was recorded in a sound treated room using a professional digital sound recorder.

Listening task 2: Group 1 participants who served as listeners were presented the 76 sentences recorded from persons with dysarthria (randomized across HP and LP conditions). The experimental set up including instructions and recording of responses were the same as in Experiment 1.

Analysis

Each correct identification of the target word by the listeners was scored as '1' and no/incorrect response as zero. The scores for correct identification of the target words (NDHP, NDLP, DHP, and DLP) of Experiment 1 (DHP, and DLP) and Experiment 2 were noted and tabulated. The total score per listener per experiment were converted to percentage score. The group mean percentage scores for correct identification of the target sounds were computed and this was subjected to statistical treatment.

Results and Discussion

The percent correct identification of the target words were calculated for 4 different conditions in Experiment 1 and 2 conditions of Experiment 2.

Section 1: Task 1 of Experiment 1

The mean percent identification of HP sentences were higher in both non degraded and degraded conditions (Table 1). Paired t-test (Table 2) revealed a significant difference for HP and LP sentences in non degraded context (t= 2.513, p< 0.05) and for HP and LP sentences in degraded condition (t=10.476, p<0.01). The results confirm the findings of studies which report that semantic predictiveness improves the listeners' scores of intelligibility for the speech of persons with dysarthria (Hunter, Pring & Martin, 1991; Garcia & Dagenais, 1998). The scores of HP non degraded condition was higher than that of the degraded, and this can probably be reasoned on the basis that the degraded condition reduced the contextual cues, further increasing the load on the finite cognitive resources required for the perception of the target stimulus. Similar observation is made by others (Lindblom, 1990a, 1990b; Duffy & Pisoni, 1992).

Table 1: *Percent correct identification and standard deviation of Experiment 1*

Analysis	Non Degraded Condition		Degraded Condition	
	HP	LP	HP	LP
Mean	97.88	95.60	68.35	48.56
SD	3.20	4.95	12.32	10.32

Table 2: *Paired t test values for Experiment 1*

Conditions	t-value	df	Sig. (2-tailed)
NDHP-NDLP	2.513	29	.01*
DHP-DLP	10.476	29	.00**

'' = Significant at 0.05 level of significance*
*'**' = Significant at 0.01 level of significance*

Table 3: *Mean percent correct identification and standard deviation of HP and LP conditions in Experiment 1*

Conditions	Overall Mean	SD
HP	62.9	27.5
LP	52.6	28.0

Table 4: *Paired sample t test for HP and LP conditions of Experiment 1*

Conditions	Mean	SD	T-value	df	Sig (2 - tailed)
HP-LP	10.34	10.11	12.536	149	.000*

'' = Significant at 0.01 level of significance*

The mean scores were higher for the HP sentences in all conditions compared to the LP sentences. Paired t test (Table 4) indicates that the difference between HP and LP sentences was highly significant (t=12.536. p< 0.01). The difference in the speech intelligibility scores can be attributed to the predictability of semantic content and grammatical structure of the sentences (Garcia & Cannito, 1996). Duffy and Giolas (1974) examined the intelligibility of words in sentences in which the words had various degrees of predictability. The contextual cues provided by the HP sentences helped the listeners to perceive the target stimulus accurately and on the other hand, absence of this in LP sentences did not help the listeners in identification of the stimuli words leading to poor intelligibility scores. Hence, it seems that the high and low predictable sentential contexts were sensitive in reflecting the competence of the listeners.

Section 2: Task 2 of Experiment 2

The mean speech intelligibility scores of HP sentences were higher when compared to LP sentences and significant when normal listeners assessed the intelligibility of speech of persons with dysarthria. The results are similar to that observed for Experiment 1, reiterating the observation that there is an advantage of HP condition over the LP condition.

Table 5: *Mean percent correct identification & standard deviation of speech intelligibility scores for HP and LP sentences of experiment 2*

Conditions	Mean	SD
HP	49.42	24.59
LP	39.53	21.65

Table 6: *Paired sample t-test of experiment 2*

Conditions	t-value	df	Sig. (2-tailed)
HP-LP	10.764	89	0.000*

'' = Significant at 0.01 level of significance*

Repeated measure ANOVA was run on the data to check the influence of listening competence on speech intelligibility measures (Table 7). The degraded version of high predictable speech sample (DHP) is significantly different from the naturally degraded sample of person with dysarthria (C_2DHP). But the scores for degraded DHP sample was similar to that of 2 persons with dysarthria (C_1DHP and C_3DHP) as confirmed by running the repeated measure of ANOVA. It is inferred that the listeners used similar cognitive resources to rate the speech intelligibility of the artificially degraded speech stimuli and naturally degraded speech sample.

Table 7: *Comparison of repeated measure ANOVA of DHP conditions of experiments 1 and 2*

Conditions		Mean Difference	Sig.
DHP	C_1DHP	0.40	1.00
	C_2DHP	49.82	0.00*
	C_3DHP	6.55	0.13

'' = Significant at 0.01 level of significance*

The degraded stimuli are significantly different in C_2DHP condition probably because the participant had severe speech intelligibility problems compared to first and third, although all the three were classified as having moderate to severe degree of speech impairment based on PCC scores. It is probable that the artificially degraded stimuli were not comparable when there is poor speech intelligibility in persons with dysarthria. However, this needs further verification.

Table 8: *Repeated measure ANOVA of DLP conditions of experiments 1 and 2*

Conditions		Mean Difference	Sig
DLP	C_1DLP	-8.57*	0.00*
	C_2DLP	35.96	0.00*
	C_3DLP	-0.31	1.00

'' = Significant at 0.01 level of significance*

The DLP sentences were significantly different ($p<0.001$) from all other speech samples of persons with dysarthria except for the third subject (C_3DLP). The difference obtained between DLP and C_2DLP could be attributed to poor speech intelligibility in subject two. But the speech samples of first and third subject was comparable with respect to intelligibility scores. Likewise, the degraded sentences for artificially and naturally degraded stimuli correlated with the third sample of person with dysarthria (C_3DLP). The inconsistency in the finding leads to the speculation that the listening competence might be varied in normal listeners' when degradation is superimposed on LP sentences. Some normal listeners might have failed to identify the target words in LP condition since the contextual cues provided is less in LP sentences along with a possible unknown interaction effect of intrinsic variables in the experimental conditions such as rate of speech of persons with dysarthria and the message predictability. These could have contributed to the observed inconsistencies. Another reason could be due to the induced variations because of the manipulation of the stimuli itself. In the artificially degraded speech of experiment 1, all the other words in the target sentences except the final word were kept undistorted whereas in the naturally degraded speech of experiment 2, all the words of a sentence were degraded. This could also be attributed to the poor scores obtained in naturally degraded stimuli compared to artificially degraded one. Though the scores of degraded sentences were different for artificially degraded and naturally degraded conditions, a correlation between the two is evident. The poorer scores in the degraded condition could be supported by the claim that the additional cognitive resources are needed to resolve ambiguous, missing, or misleading acoustic-phonetic cues which are generally present in the degraded stimuli. It is known that human beings employ finite cognitive resources and the degraded stimuli demand for a higher processing which in turn reduces the performance of listeners on degraded sentence stimuli (Duffy & Pisoni, 1992).

Table 9: *Pearson Product–Moment Correlation Coefficients for different conditions.*

		Non Degraded	Degraded	Client 1	Client 2	Client 3
Degraded	Pearson Correlation	.219	1	.673**	.334**	.600**
	Sig. (2-tailed)	.092	-	.000	.009	.000
	N	60	60	60	60	60

*** = positively correlated*

Pearson Product- Moment correlation of artificially degraded condition with all other stimuli conditions of experiment 1 & 2 was carried out (Table 9). There is a positive correlation between the degraded stimulus and the speech samples of persons with dysarthria. This suggests that speech intelligibility ratings for artificially degraded stimuli were comparable to that of naturally degraded speech samples of persons with dysarthria. However, caution needs to be exercised while commenting on the competence of normal listeners across degraded low predictable sentences, since there is a significant difference between performance with artificially degraded stimuli and that of moderate to severe speech intelligibility deficit of persons with dysarthria (C_1DLP & C_2DLP) (Table 8). Also, the difference between the artificially degraded speech stimuli and naturally degraded sample of C3 which is statistically non significant shows that there is a differential sensitivity for the low predictable speech stimuli indicating that the low predictable stimuli are sensitive and have the potential of truthfully tapping the listening competence of normal listeners. This study is carried out on a small sample (especially in the group of persons with dysarthria). It is likely that inclusion of more samples would have indicated clear trends in the listening competence.

Conclusions

Based on the performance of the listeners in the two experimental conditions, it is concluded that there exists a difference in listening competence across degraded and non degraded high and low predictable sentential context. The degraded HP speech stimuli of persons with dysarthria are similar to the artificially induced degradation of speech stimuli. The influence of listening competence is masked in the HP sentence since it is possible that the contextual cues would have helped the listener to predict the target words. Since the degraded low predictable sentences removes the contextual cues, the true listening competence is reflected in this condition. Hence LP sentences could be used to tap the listening competence of the normal listeners.

Implications

The study provides an insight into the clinical assessment of speech intelligibility task. While assessing the speech intelligibility, the listening competence of the listeners may be understood through the use of low predictable sentences. This observation is based on the outcome of the results seen in two experiments that low predictable stimuli can act as a true measure of listening competence in normal listeners. If the listening competence is not considered during the assessment of speech intelligibility, then varied results for different listeners may become evident, ultimately affecting the scores of speech intelligibility of individuals with dysarthria.

References

Barkmeier, J. M., Jordan, L. S., Robin, D. A., & Schum, R. L. (1991). Inexperienced listener ratings of dysarthric speaker intelligibility and physical appearance. In *C. Moore, & K. Yorkston (Eds.), Dysarthria and apraxia of speech: Perspectives on management*. 65–75, Baltimore,MD: Brookes.

Beukelman, D. R., & Yorkston, K. (1979). The relationship between information transfer and speech intelligibility of dysarthric speakers. *Journal of Communication Disorders, 12,* 189–196.

Dagenais, P. A., Watts, C. R., Turnage, L. M., & Kennedy, S. (1999). Intelligibility and acceptability of moderately dysarthric speech by three types of listeners. *Journal of Medical Speech-Language Pathology, 7,* 91–95.

Drager, K. D., & Reichle, J. E. (2001). Effects of age and divided attention on listeners' comprehension of synthesized speech. *Augmentative and Alternative Communication, 17,* 109–119.

Duffy, J. R. (2005). *Motor speech disorders: Substrates, differential diagnosis, and management* (2nd Ed.). St. Louis, MO: Elsevier Mosby.

Duffy, S. A., & Pisoni. (1992). Comprehension of synthetic speech produced by rule: a review and theoretical interpretation. *Language Speech, 35,* 351-389.

Duffy, J., & Giolas, T. (1974). Sentence intelligibility as a function of key word selection. *Journal of Speech and Hearing Research, 17,* 631–637.

Eisenberg, L. S., Shannon, R. V., Martinez, A. S., Wygonski, J., and Boothroyd, A. (2000). Speech recognition with reduced spectral cues as a function of age. *Journal of the Acoustical Society of America, 107*, 2704-2710.

Garcia, J., & Cannito, M. (1996). Influence of verbal and nonverbal contexts on the sentence intelligibility of a speaker with dysarthria. *Journal of Speech and Hearing Research, 39,* 750–760.

Garcia, J. M., & Dagenais, P. A. (1998). Dysarthric Sentence Intelligibility: Contribution of iconic gestures and message predictiveness. *Journal of Speech and Hearing Research, 41,* 1282-1293.

Higginbotham, D. J., Drazek, A. L., Kowarsky, K., Scally, C., & Segal, E. (1994). Discourse comprehension of synthetic speech delivered at normal and slow presentation rates. *Augmentative and Alternative Communication, 10*, 191–202.

Hunter, L., Pring, T., & Martin, S. (1991). The use of strategies to increase speech intelligibility in cerebral palsy: An experimental evaluation. *International Journal of Language & Communication Disorders,* 26, 163-174.

Hustad, K.C., & Beukelman, D.R. (2002). Listener comprehension of severely dysarthric speech: Effects of linguistic cues and stimulus cohesion. *Journal of Speech, Language, and Hearing Research, 45,* 545-558.

Hustad, K. (2006). Estimating the intelligibility of speakers with dysarthria. *Folia Phoniatrica, 58*, 217–228.

Hustad, K. C., & Cahill, M. A. (2003). Effects of presentation mode and repeated familiarization on intelligibility of dysarthric speech. *American Journal of Speech-Language Pathology*, 12, 198–208.

Kalikow, D. N., Stevens, K. N., Elliott, L. L., (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. *Journal of Acoustical Society of America, 61*, 1337-1351.

Kent, R.D., Weismer, G., Kent, J.F., & Rosenbek, J.C. (1989). Toward phonetic intelligibility testing dysarthria. *Journal of Speech and Hearing Disorders, 54*, 482-499.

Kertesz, A. (1982). *Western Aphasia Battery Test Manual*. The Psychological Corporation.

King, J. M., & Gallegos-Santillan, P. (1999). Strategy use by speakers with dysarthria and both familiar and unfamiliar conversational partners. *Journal of Medical Speech-Language Pathology, 7,* 113–116.

Lindblom, B. (1990a). Explaining phonetic variation: A sketch of the H & H theory. In W.J. Hardcastle & A. Marchal (Eds.), *Speech production and speech modeling*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Lindblom, B.(1990b). On the communication process: Speaker-listener interaction and the development of speech. *Augmentative and Alternative Communication*, 6, 220–230.

Miller, G.A., Heise, G.A., and Lichten, W. (1951). The intelligibility of speech as a function of

the context of the test materials. *Journal of Experimental Psychology, 41,* 329-335.

Nygaard, L., & Pisoni, D. (1998). Talker- specific learning in speech perception. *Perception and Psychophysics*, *60,* 355-376.

Schiavetti, N. (1992). Scaling procedures for the measurement of speech intelligibility. In R. Kent (Ed.), *Intelligibility in speech disorders*, Amsterdam: Benjamins.

Shriberg, L. D., & Kwiatkowski, J. (1982). Phonological Disorders II: A Conceptual Framework for management. *Journal of speech and hearing disorders*, *47,* 242-256.

Tjaden, K. K., & Liss, J. M. (1995a). The influence of familiarity on judgments of treated speech. *American Journal of Speech Language Pathology, 4*, 39–48.

Weismer, G., & Martin, R. (1992). Acoustic and perceptual approaches to the study of intelligibility. In R. Kent (Ed), *Intelligibility in speech disorders*, Philadelphia: John Benjamins Publishing Co.

Weismer, G., Jeng, J.Y., Laures, J. S., Kent, R. D., & Kent, J. F. (2001). Acoustic and intelligibility characteristics of sentence production in neurogenic speech disorders. *Folia Phoniatrica et Logopaedica, 53*, 1–18.

Yorkston, K. M., & Beukelman, D. R. (1981). *Assessment of intelligibility in dysarthric speech.* Tigard, OR: CC Publications.

Yorkston, K. M., & Beukelman, D. R., (1983). The influence of judge familiarization with the speaker on dysarthric speech intelligibility. In W. Berry (ed.), *Clinical Dysarthria* Boston, MA: College Hill Press), pp. 155–163.

Yorkston, K. M., Beukelman, D. R., Strand, E. A., & Bell, K. R. (1999). *Management of motor speech disorders in children and adults* (2nd ed.). Austin, TX: Pro Ed.

Appendix I

Sl. No.	High Predictable sentences	Sl. No	Low Predictable sentences
1.	The old train was powered by coal.	1.	I am thinking about the consequences.
2.	My T. V. has a twelve inch screen.	2.	Tom wants to know about the course.
3.	The boat sailed along the river.	3.	The girl talked about the jewels.
4.	She wore a feather in her cap.	4.	The girl knows about the meeting.
5.	I made a phone call from a booth.	5.	The farmer harvested this season.
6.	His boss made him work like a donkey.	6.	They did not discuss the problem.
7.	Football is a dangerous game.	7.	I had a problem with the circuitry.
8.	Drop the coin through the slit.	8.	Peter should speak about the truth.
9.	Peter should speak about the truth.	9.	I want to know about the rules.
10.	Hold the baby on your arms.	10.	Jane has a problem with the house.
11.	Tear off some paper form the book.	11.	The old man thinks about the future.
12.	The candle flame melted the wax.	12.	Ann was interested in the music.
13.	The hockey player scored a goal.	13.	Tom is talking about the promotion.
14.	They played a game of cat and mouse.	14.	Ruth’s grandmother discussed the plan.
15.	A Chimpanzee is an animal.	15.	I want to speak about the incident.
16.	The doctor charged a low fee.	16.	I have not discussed the questions.
17.	The cushion was filled with sponge.	17.	You could not have discussed the doubt.
18.	Stir your coffee with a spoon.	18.	We have spoken about the deal.
19.	At breakfast he drank some coffee.	19.	She wants to talk about the guy.
20.	Banks keep their money in a locker.	20.	The old man considered the proposal.
21.	A bicycle has two wheels.	21.	You want to talk about the subject.
22.	Ann works in the bank as a clerk.	22.	She might have discussed the results.
23.	The nurse gave him the first aid.	23.	Peter knows about the accident.
24.	Kill the bugs with this pesticide.	24.	The boy can’t talk about the secret.
25.	The sick child swallowed the pills.	25.	We’re glad Ann asked about the misunderstanding.
26.	The swimmer dove into the pool.	26.	Miss white thinks about the health.
27.	We heard the ticking of the clock.	27.	We could discuss the agenda.
28.	The team was trained by their coach.	28.	I did not know about the match.
29.	He got drunk in the local bar.	29.	Nancy did not discuss the kidnap.
30.	The girl swept the floor with a broom.	30.	I am talking about the serial.
31.	The firemen heard her frightened scream.	31.	The woman knew about the treatment.
32.	The landlord raised the rent.	32.	Tom won’t consider the excuse.
33.	To open the jar, twist the lid.	33.	The man spoke about the program.
34.	Spread some butter on your bread.	34.	Miss white doe not discuss the murder.
35.	The chicken pecked corn with its beak.	35.	I’m glad you heard about the frog’s sound.
36.	The detectives searched for a clue.	36.	Mr. White spoke about the engagement.
37.	Watermelon has lots of seeds.	37.	Marry has not discussed the issue.
38.	Old metal cans were made with tins.	38.	Miss White doesn’t discuss the quarrel.

LARYNGEAL AERODYNAMIC MEASURES IN NORMAL ADULTS

[1]Gopi Kishore Pebbili, [2]Pushpavathi M. & [3]Sheela S.

Abstract

Laryngeal aerodynamic analysis measures respiratory and laryngeal functions reflecting the coordinative nature of voice production. The present study primarily aimed at establishing the normative data for four laryngeal aerodynamic parameters viz. Estimated Sub- Glottic Pressure (ESGP), Mean Air Flow Rate (MAFR), Laryngeal Airway Resistance (LAR), and Laryngeal Airway Conductance (LAC) in adult Indian population. A second purpose was to examine the effect of age and gender on these measures. Eighty five participants including 54 males and 31 females in the age range of 18-40 years, with no known problems in voice were considered for the study. Aeroview from Glottal Enterprises was used to record and analyze the data. The participants were instructed to produce CV syllable train "papapapa" into the circumvented mask at comfortable loudness and pitch. Thus recorded stimuli were analyzed to obtain all four parameters (mentioned earlier). Mean and standard deviation for the all the parameters were calculated separately for both the groups of males and females. Box plots were drawn and 8 outliers were removed manually from the main data. Two way MANOVA (performed on remaining data) revealed significant main effects of age for the parameters ESGP and LAC. No significant main effects of gender were observed for the any of the laryngeal aerodynamic parameters studied. The data obtained from this study can be used as normative for laryngeal aerodynamic analysis in the adult population in the age range of 18–40 years.

Keywords: *Estimated Sub-Glottic Pressure, Laryngeal Airway Resistance, Normative data.*

Voice production involves the coordinated interactions of the respiratory, phonatory and resonatory subsystems. It is an aerodynamic process in which the laryngeal modulations of respiratory airflow create the acoustic waves that are subsequently modified by vocal tract resonances. The acoustic analysis of voice provides information on the source and filter characteristics. The Static respiratory analysis provides information on the respiratory volumes. However, these measures represent the individual phonatory and respiratory subsystems and might not reflect the coordinative interactions of these systems in voice production. Therefore, a combined measurement that captures the relations among/relationship between respiratory and laryngeal functions is essential to reflect the coordinated nature of these systems in voice production.

Laryngeal aerodynamic measures such as maximum phonation duration, S/Z ratio, mean air flow rate (MAFR), estimated sub-glottal pressure (ESGP), laryngeal airway resistance (LAR), laryngeal airway conductance (LAC), phonatory power, vocal efficiency, phonation threshold pressure, etc provide information's about efficiency of the glottis valve during phonation (Grillo, Perta & Smith, 2009). The laryngeal aerodynamic measure such as MAFR and ESGP has been studied extensively to investigate the relationship between these measures and phonatory processes (Hill man, Holmberg, Perkell, Walsh & Vaughan, 1989; Iwata, Von Leden & Williams, 1972; Netsell, Lotz & Shaughnessy, 1984). MAFR is the volume of air flow across the vocal folds during phonation in one second. It is generally measured in liters or milliliters per second (l/s or ml/s). Subglottic pressure is the amount of pressure required to generate and sustain the oscillation of the vocal cords during voice production. It is often measured in centimeters of water (cm H_2O). Laryngeal airway resistance (LAR) is the ratio of estimated subglottal pressure to mean air flow rate (Smitheran & Hixon, 1981) and reflects the resistance offered by the vocal folds to airflow at glottic level. Laryngeal airway conductance (LAC) is the ratio of mean air flow rate to the estimated subglottal pressure. It is the converse of LAR and reflects the conductance for airflow at the level of glottis. Both LAR and LAC are the derived parameters.

Very few studies have focused on establishing normative data of adults in the age range of 18-40 years for laryngeal aerodynamic parameters ESGP, MAFR, LAR, and LAC. Stathopoulos and Sapienza (1993) investigated the simultaneous function of the laryngeal and respiratory systems during changes in three vocal intensity levels (soft, comfortable, loud) during the repetition of syllable /pa/. Ten males and ten females in the age range of 20- 30 years served

[1]Lecturer in Speech Pathology, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: gopiaslp@gmail.com, [2]Professor in Speech Pathology, AIISH, Mysore-06, Email: pushpa19@yahoo.co.in & [3]Research officer, AIISH, Mysore-06, Email: sheela.mslp@gmail.com

as subjects. The laryngeal parameters such as maximum flow declination rate (MFDR), LAR, open quotient (OQ), tracheal pressure, translaryngeal flow were measured using Pneumota chometer Model MS 100 A-2. The laryngeal results revealed significant increase in MFDR and LAR and significant decrease in OQ during changes in three vocal intensity levels. A statistical gender effect was found for MFDR and OQ parameters. Male subjects had higher MFDR than female subjects and female had higher OQ values than males at each intensity level. The LAR increased in both male and female group consistently as vocal intensity increased. The authors concluded that examination of simultaneous laryngeal and respiratory system provides broad description of interactive patterns used during speech production.

Goozee, Murdoch, Theodoros, and Thompson (1998) obtained the respiratory measures of 56 male and 53 female normal adults in the age group of 20 to 80 years. They analyzed aerodynamic parameters such as ESGP, LAR, phonatory airflow, phonatory SPL, phonatory power and phonatory efficiency using Aerophone II Model 6800. The results indicated high inter-subject variability for the parameters: - phonatory airflow, LAR, phonatory power and phonatory efficiency, whereas the phonatory SPL and ESGP were reported to be most consistent. Further, among the parameters investigated, significant age and gender effects were reported only for MAFR. The 20-30 year-old subjects produced significantly lower MAFR values than the 31-40 and 41-50 year old subjects. The females had significantly higher MAFR values than males. These results are attributed to the male or female subjects making laryngeal and respiratory behavioral adjustments, differences in methodology and instrument employed and the subject group tested. The parameters ESGP, LAR, phonatory power, phonatory efficiency and phonatory SPL (during running speech vowel /i/ and / u/) were found to be independent of age and gender.

Hiss, Treole, and Stuart (2001) measured peak intraoral air pressure (P_0) in sixty adult participants in the age range of 20 to 83 years. The subjects were divided into three age groups (20-39, 40-59, & 60-83), comprising of 10 males and 10 females in each age group. Aerophone II Model 6800 was used for analysis of P_0 during voiceless stop plosive /p/ productions in repeated CV combinations. Repeated trials of measurement of P_0 resulted in negligible mean difference between trials. Further P_0 was also not found to be varying as a function of age or gender ($p > 0.05$). Based on these findings, the authors concluded that P_0 was a stable measure within a short sampling session.

Weinrich, Salz, and Hughes (2005) assessed 33 boys and 37 girls between the age range 6 - 10.11 years. The Pneumotachometer Model MS 100 A-2 was used to obtain aerodynamic measures such as Open quotient (OQ), Speed quotient (SQ), Maximum Flow Declination Rate (MFDR), Sub-Glottal Pressure (ESGP). These parameters were examined as a function of vocal frequency (low, comfort, & high). The results did not reveal age or gender effect for any of the aerodynamic measures studied. However, they observed a trend of decrease in ESGP with age and slightly higher ESGP values for female children than for male children across all the frequencies.

In a recent study Zraick, Olinde, and Shotts (2012) evaluated 68 male 89 female normal adults in the age range of 20-86 years. Further, the subjects were subdivided into three age groups including 18-39 years, 40-59 years and 60-80 years. The Phonatory Aerodynamic System Model 6600 was used to analyze 41 aerodynamic measures. The results revealed statistically significant main effect of age on measures for peak expiratory airflow, expiratory volume, mean SPL, SPL range and Mean F_0. A statistically significant main effect of gender was found for mean F_0. Based on the findings, authors opined that one must account for age and gender variables during laryngeal aerodynamic analysis as changes related to these variables were found for some measures.

The laryngeal aerodynamic parameters have been found to be useful in discriminating normal from dysphonic voices. Some of these parameters such as ESGP, LAR were robust and aid in diagnosing conditions such as vocal hyperfunction or muscle tension dysphonia. Despite these merits, there have been very few attempts made to establish normative database for these parameters. Although few studies established the normative data, the sample size used was small and scattered over a vast age range. The normative data reported by the earlier studies for the laryngeal aerodynamic parameters ESGP, MAFR, LAR, and LAC for subjects in the age range of 18-40 years is summarized in the table 1.

Table 1: *Normative values (Mean and Standard deviation) for ESGP, MAFR, LAR and LAC*

Laryngeal aero-dynamic measures		Stathopoulos et al., (1993)	Goozee et al., (1998)		Hiss et al., (2001)	Zraick et al., (2012)
		Pneumotachometer Model (MS 100 A-2)	Aerophone II Model 6800		Aerophone II Model 6800	Phonatory Aerodynamic System Model 6600
		20-30yrs	**20-30yrs**	**30-40yrs**	**20-39 yrs**	**18-39 yrs**
ESGP (cm H2O)	M	-	9.34 (± 1.87)	6.56 (± 2.08)	-	6.65 (±1.98)
	F	-	6.73 (± 1.47)	7.9 (±1.33)	5.55-6.79	5.4 (± 1.37)
MAFR (L/s)	M	-	0.52 (±0.27)	0.38 (±0.29)	-	0.38 (±0.34)
	F	-	0.39 (±0.25)	0.5 (±0.19)	-	0.16 (±0.08)
LAR (cm H2O/ L/s)	M	50.43* (±23.37)	30.58 (±35.0)	48.1 (±57.84)	-	79.44 (±120.0)
	F	40.62* (±13.67)	26.4 (±20.53)	18.26 (±8.23)	-	68.20 (±53.08)
LAC (L/s/cm H2O)	M	-	-	-	-	-
	F	-	-	-	-	-

- Not studied, * included values obtained at comfortable intensity level only

Further, all the above mentioned data was reported on the western population. However, literature reveals that the aerodynamic measures vary across geographical and ethnic groups. For instance Miller and Daniloff (1993) opined that aerodynamic parameters such as MAFR are influenced by a number of anatomical features and physiological events, such as the driving pressure arising from the respiratory system, the constriction, size and timing of movements of the vocal cords, together with the size, shape and biomechanical properties of the vocal tract as a whole. Also, Rajeev (1995) reported that the maximum phonation time (MPT), which is an aerodynamic parameter is found to be less in the Indian population compared to western norms.

Hence, it is essential to establish the normative data for laryngeal aerodynamic parameters in the Indian population. Also, earlier studies had reported that some of the laryngeal parameters were influenced by age and gender of the participants. However, other studies had contradicted these results and said that the same laryngeal aerodynamic parameter was influenced by either age or gender, making this issue unresolved. For example, Goozee et al. (1998) reported that the MAFR values was affected by both age and gender, whereas Zraick et al. (2012) reported that the MAFR values was affected by only age. Therefore, the present study established normative data for the laryngeal aerodynamic parameters: Estimated Sub- Glottic Pressure, Mean Air Flow Rate, Laryngeal Airway Resistance, and Laryngeal Airway Conductance (LAC) in adult population in the age range of 18 to 40 years and investigated the effect of age and gender on the laryngeal aerodynamic measures.

Method

Participants: Eighty five participants (fifty four males & thirty one females), in the age range of 18-40 years divided into two groups of 18-25 years and 26-40 years, participated in the study. The participants selected were with no history of upper respiratory tract infection, speech or voice problems, laryngeal injury or surgery, neurological condition. The participants with voice or respiratory related problems and active laryngeal or pharyngeal infections were not included in the study.

Instrumentation: The Aeroview 1.4.4 version (Glottal Enterprises Inc, USA) was used to collect aerodynamic data from each participant. The Aeroview is a computer-based system that measures the MAFR and ESGP pressure during vowel production. The derived parameters such as LAR (ESGP/MAFR) and LAC (MAFR/ESGP) using an automated factory-optimized algorithm are also displayed. Other measures of voice such as the Sound Pressure Level (SPL) and the Fundamental Frequency (F_0) of the measured vowel segment phonation and the Phonatory Threshold Pressure (PTP) can also be obtained.

Instrument calibration: Before recording, the transducers for measuring airflow and air pressure were calibrated on daily basis as per the guidelines provided by Glottal Enterprises.

Recording: The participants were seated comfortably and the procedure was explained clearly. The participants were instructed to hold the mask firmly against the face so that nose and mouth were covered with the intraoral tube placed between the lips and above the tongue. The examiner confirmed the correct placement of the transducer or ensured that the mask is firmly fitted. The participants were then instructed to produce the repetitions of CV syllable /pa/ 6-7 times into the circumvented mask at a comfortable pitch and loudness to obtain six to seven stable peaks of intraoral pressure. The rate and style of production was demonstrated by the examiner and two practice runs were given before the actual recording. Following practice, the actual recordings were made. The recording with syllable production rate between 2.0 to 3.5 per second (recommended by manufacturer) and with appropriate pressure peak morphology was considered for the further analysis. Typical pressure peak and airflow wave morphology are shown in figure 1.

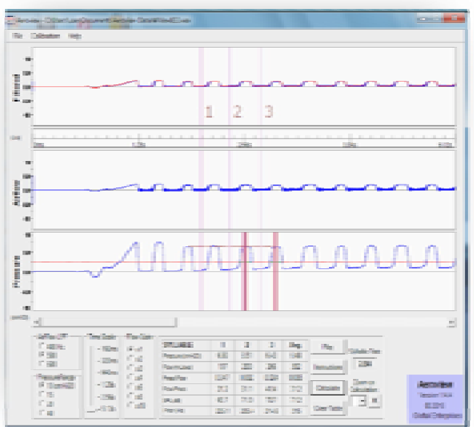

Figure 1: *Typical morphology of appropriate pressure peak and airflow wave*

Analysis: The recorded waveform was analyzed by placing the cursors on flat portions of two adjacent pressure peaks. The application software analyzes the waveform and provides the values of Estimated Sub-Glottic Pressure (cmH_2O), Mean Air Flow Rate (ml/sec), Laryngeal Airway Resistance (cmH_2O/ml/sec), Laryngeal Airway Conductance (ml/sec/cmH_2O) values. On obtaining three peak to peak measurements, the software automatically provides their average value. In order to facilitate comparison of MAFR values with earlier studies, MAFR which is obtained in ml/sec was converted manually to Liters/sec. Accordingly, derived parameters such as LAR and LAC obtained values were converted to (cmH_2O/L/sec) and (L/sec/cmH_2O) respectively.

Statistical analysis: Statistical Package for Social Sciences (SPSS) version 18.0 was used to perform all the statistical analysis. Descriptive statistical measures mean and standard deviation for the all the parameters were calculated separately for both the age groups and across the gender. Two way multivariate analysis of variance (MANOVA) was conducted to verify the main effects of independent variables on the dependent variables. Age (2 levels) and gender (2 levels) served as the independent variables, and the parameters measured (ESGP, MAFR, LAR, LAC) served as the dependent variables.

Results

zUsing the obtained data from 85 participants, box plots were drawn using SPSS 18.0 considering all the four laryngeal aerodynamic parameters. The possible outliers were identified from the box plots and were removed manually from the main data. Following the outlier removal, further statistical procedures were performed on a total of remaining 77 participants (47 males & 30 females).

Normative value for laryngeal aerodynamic parameters: The mean and standard deviation of ESGP (Figure 2a) in 18-25 years males was 4.62 cm H_2O (±1.20) and in 26- 40 years males was 5.48 cm H_2O (±0.94) and in 18-25 years females was 4.98 cm H_2O (±1.63) and 26- 40 years females was 5.93 cm H_2O (±1.53). The mean and standard deviation values of MAFR (Figure 2b) in 18-25 years males was 0.25 L/s (±0.14) and in 26-40 years males was 0.26 L/s (±0.13) and in 18-25 years females was 0.26 L/s (±0.16) and 26- 40 years females was 0.24 L/s (±0.10). The males between the age range of 18-25 years and 26-40 years obtained an average LAR value (Figure 2c) of 22.56 cmH_2O/L/s (±11.92) and 26.53 cmH_2O/L/s (±15.00) while in females it was 24.21 cmH_2O/L/s (±15.14) and 28.63 cmH_2O/L/s (±16.04) respectively. In general, ESGP and LAR values increase in both groups across age. The average LAC values (Figure 2d) in males between the age range of 18-25 years was 0.05 L/s/cmH_2O (±0.03) and 26-40 years was 0.04 L/s/cmH_2O (±0.22) and in females between the age range of 18-25 years was 0.06 L/s/cm H_2O (±0.04) and 26-40 years was 0.04 L/s/cmH_2O (±0.02).

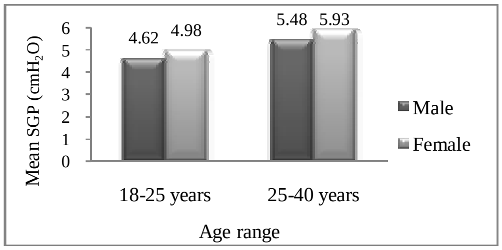

Figure 2 (a): *Mean values of ESGP (cmH_2O)*

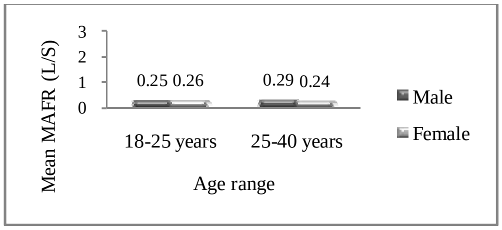

Figure 2 (b): *Mean values of MAFR (L/S)*

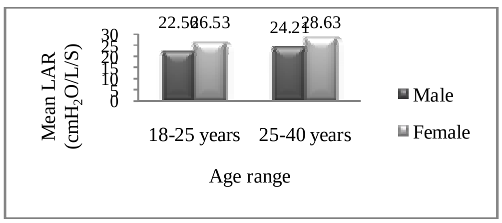

Figure 2 (c): *Mean values of LAR (cmH_2O/L/S)*

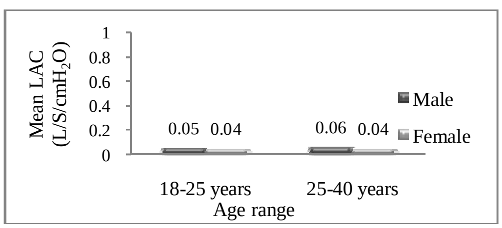

Figure 2 (d): *Mean values of LAC (L/S/ cmH_2O)*

a) **Effect of age and gender on Laryngeal Aerodynamic parameters:** The two way MANOVA (Table 2) did not reveal significant main effects for gender across all the LA parameters except the ESGP which was found to be significant at $p< 0.05$ level. A main effect of age was observed for the ESGP and LAC parameter. The ESGP values were shown to be higher in both male and female older age group and LAC values were higher only in male older age group. MANOVA did not reveal interaction effects of independent variables age and gender. Since, there was no significant gender effect across all four laryngeal aerodynamic measures, mean for each of the laryngeal aerodynamic measures was calculated using formula-Total score of all subjects/total number of subjects. Thereby, range (min-max) and SD was also calculated. The 95 % confidence intervals for each of the laryngeal aerodynamic parameter are shown in table 3.

Table 2*: Two- way MANOVA interaction effects*

Type of effect	Laryngeal aerodynamic measures	*p* values
Age effect	ESGP(cm H_20)	0.004*
	MAFR(L/s)	0.649
	LAR (cm H_20/ L/s)	0.217
	LAC (L/s/ cm H_20)	0.052*
Gender effect	ESGP(cm H_20)	0.186
	MAFR(L/s)	0.767
	LAR (cm H_20/ L/s)	0.579
	LAC(L/s/ cm H_20)	0.890
Age*Gender effect	ESGP(cm H_20)	0.881
	MAFR(L/s)	0.366
	LAR (cm H_20/ L/s)	0.947
	LAC (L/s/ cm H_20)	0.380

* Parameters found to be significant at $p<0.05$

Table 3*: 95 % level of confidence interval across subjects for the laryngeal aerodynamic measures*

Laryngeal Aerodynamic measures	Age range	95 % Confidence interval formula for Mean Mean	Lower Bound	Upper Bound
ESGP (cm H_20)	18-25 years	4.74	4.30	5.19
	26-40 years	5.68	5.27	6.08
MAFR (L/s)	18-25 years	0.26	0.21	0.31
	26-40 years	0.25	0.21	0.29
LAR (cm H_20/ L/s)	18-25 years	0.23	18.87	27.37
	26-40 years	0.27	22.49	32.40
LAC(L/s/ cm H_20)	18-25 years	0.05	0.04	0.06
	26-40 years	0.04	0.03	0.05

Discussion

This first aim of the study was aimed to establish normative data for the for four laryngeal aerodynamic parameters Estimated Sub-Glottic Pressure, Mean Airflow rate, Laryngeal Airway Resistance and Laryngeal.

Airway Conductance in adult population in the age range of 18 to 40 years. Because, Sharma and Goodwin (2006) reported that the lung function undergo a developmental phase and maturation phase during the first two decades of life and achieve maximal lung function will be achieved by 20 years of age in female and 25 years of age in males. The ESGP and MAFR values obtained from the present study vary from the earlier studies by Gooze et al. (1998), Hiss et al. (2001), and Zraick et al. (2012). This can be attributed to the variation in the age group and number of participants considered. The study by Gooze et al. (1998) considered 20-30 years and 30-40 years including 5 male and 5 female in each group, whereas Hiss et al. (2001) considered 20-39 years including 10 male and 10 female and Zraick et al. (2012) considered 18-39 years including 32 male and 47 female.

The LAR values obtained from the present study is different from the earlier normative studies by Stathopoulos et al. (1993), Gooze et al. (1998) and Zraick et al. (2012). This can be attributed to the variation in different instruments used, stimuli as well as the recording protocol. The present study used Aeroview instrument for laryngeal aerodynamic analysis and subjects were instructed to produce the repetitions of CV syllable /pa/ 6-7 times into the circumvented mask at a comfortable pitch and loudness to obtain six to seven stable peaks of intraoral pressure. But Stathopoulos et al. (1993) used Pneumotachometer Model (MS 100 A-2) and the subjects were asked to produce and utterance of a syllable train consisting of seven repetitions of /pa/ at three intensity levels (soft, comfortable and loud) into the circumferentially vented wire screen pneumotachograph mask which consists of both air pressure and airflow transducer. Gooze et al. (1998) used Aerophone II Model 6800 and subjects were asked to repeat the consonant vowel sequence, /ipipipi/ for several seconds into mask of the transducer module until recording was done, whereas Zraick et al. (2012) used Phonatory Aerodynamic System (PAS) and subject were instructed to repeat the voiced vowel /a/ and the voiceless stop plosive /p/ nine times in vowel or consonant format (i.e.,/apapapapapapapa/, placing equal stress on each syllable into the hand-held module consisting of both air pressure and airflow transducer. The derived parameter LAC has not been explored in previous studies and the current study provides normative data for the same. The reliability of using LAC measure as an effective tool to quantify laryngeal aerodynamic changes has to be further established using a larger sample size and its correlation with other laryngeal aerodynamic measures.

The second aim of the study was to investigate the effect of age and gender on laryngeal aerodynamic measures. Table 2 indicates statistically significant main effect of age on the parameter ESGP. The ESGP value was observed to be increasing with age, i.e., the higher ESGP values were observed for the 26-40 years than 18-25 years age group. The difference observed across the age may be attributed to age-related anatomical and physiological changes in the respiratory and laryngeal system. Mittman, Edelman and Norris (1965) reported reduction in chest wall compliance in adults compared to young adults. Also, Sharma and Goodwin (2006) reported that lung function remains steady with very minimal change from age 20 to 35 years and starts declining thereafter. In general, Kahane (1987) has reported that age related changes in anatomy have the ability to affect the laryngeal valve airstream mechanism that takes place during phonation and thereby ESGP measure. The results of the present study are inconsistent with earlier findings reported by Goozee et al. (1998); Hiss et al. (2001) and Zraick et al. (2012) who did not find age effect on ESGP. From the Table 1, it is also evident that there is no statistically significant main effect of gender for the parameter ESGP. This finding is consistent with the previous reports from Goozee et al., (1998), Hiss et al, (2001), Ketelslagers, De Bodt, and Wuyts and Heyning (2007) and Zraick et al. (2012), who also reported that ESGP was least affected across the subjects among all the parameters of laryngeal aerodynamics.

The MAFR parameter was not affected by the age and gender of the participants ($p>0.05$) (Table 2). This result is supported by the findings of Hiss et al. (2001), who did not find effect of age and gender on MAFR. Stathopoulos and Sapienza (1993) also did not find significant gender differences and opined that phonatory airflow represents the effects of both laryngeal valving and vocal tract function. Based on this, they proposed that factors such as supraglottal resistance may have affected the airflow values that they obtained. However, Goozee et al. (1998) reported that the MAFR was affected by both age and gender, whereas Zraick et al. (2012) reported that the MAFR was affected by only age. This may be attributed to that fact that these studies considered a wider range of age groups including geriatric population. However, the present study considered participants in the age range of 18-40 years only.

The LAR parameter was not affected by the age and gender of the participants ($p > 0.05$) (Table 2). Laryngeal airway resistance cannot be measured directly, but rather is calculated as the ratio of estimated subglottal pressure to phonatory flow rate (Smitheran & Hixon, 1981). As no significant gender effects were found for the MAFR and ESGP parameters in the present study, the finding that the male and female subjects also exhibited similar laryngeal airway resistances was not unexpected. These findings are in consistent with the previous reports from Goozee et al., (1998) and Zraick et al., (2012). The LAC parameter (Table 2) is not found to be affected by gender of the participants. But, age was found to have a statistically significant effect on this parameter at $p < 0.05$ level (Table 2). However, the reliability of the same has to be further established using a larger sample size and its correlation with other laryngeal aerodynamic measures.

Conclusions

The present study aimed to establish normative database for adults in some of the laryngeal aerodynamic parameters across in the age range of 18-40 years. The ESGP and MAFR findings were inconsistent with earlier studies due difference in age group and number of participants in that sub-age group (Gooze, et al. 1998, Hiss, et al. 2001, Zraick, et al. 2012). The LAR and LAC findings were also inconsistent with earlier studies because of different instruments used, stimuli as well as the recording protocol (Stathopoulos, et al. 1993, Gooze, et al. 1998, Zraick, et al. 2012).The age related changes were found for some laryngeal aerodynamic measures such as ESGP and LAC. In addition, all the laryngeal aerodynamic measures were found to be independent of the effect of gender. The normative data established in the present study (Appendix 1) can be used clinically in the assessment of voice disorders and for research purposes. Further research into the development of Indian normative data and effects of age and gender on laryngeal aerodynamic measures across ages including pediatric and geriatric population is required. Since there is a dearth of clinical data regarding the laryngeal aerodynamic analysis in individuals with various disorders, further studies in these lines is warranted.

References

Al-Malki, K. H. (2005). Aerodynamic Analysis of Vocal Fold Polyps. *Saudi Journal of Oto-Rhino-Laryngology Head and Neck Surgery, 7 (1)*, 5-9.

Baken, R. J. (1987), *Clinical Measurement of Speech and Voice*. Boston, MA: College-Hill Press.

Bard, M.C., Slavit, D. H., Mc CaVrey, T.V., & Lipton, R. J. (1992). Noninvasive technique for estimating subglottic pressure and laryngeal efficiency. *Annals of Otology Rhinology and Laryngology,* 101, 578-582.

Goozee, J. V., Murdoch, B. E., Theodoros, D. J., & Thompson, E. C. (1998). The effects of age and gender on laryngeal aerodynamics. *International Journal of Language and Communication Disorders*, 33, 221-238.

Grillo, E. U., Perta, K., & Smith. L. (2009). Laryngeal resistance distinguished pressed, normal, and breathy voice in vocally untrained females. *Logopedics Phoiatrica Vocology,* 34 (1), 43-48.

Grillo, E. U., & Verdolini, K. (2008). Evidence for distinguishing pressed, normal, resonant, and breathy voice qualities by laryngeal resistance and vocal efficiency in vocally trained subjects. *Journal of Voice,* 22, /546-552.

Hertegrad, S., GauYn, J., & Lindestad, P. A. (1995). A comparison of subglottal and intraoral pressure measurements during phonation. *Journal of Voice*, 9, 149-155.

Hillman, R, E., Holmberg, E. B., Perkell, J, S., Walsh, M., & Vaughan, C. (1989). Objective assessment of vocal hyperfunction: an experimental framework and initial results. *Journal of Speech and Hearing Research,* 32, 373–392.

Hiss, S. G., Treole, K., & Stuart, A. (2001). Effect of age, gender, and repeated measures on intraoral air pressure in normal adults. *Journal of Voice,* 15, 159-164.

Hoit, J. D., & Hixon, T. J. (1987). Age and speech breathing. *Journal of Speech Hearing Research,* 1987, 30, 351–366.

Iwata. S., Von Leden. H. & Williams. D. (1972). Airflow measurement during phonation. *Journal of Communication Disorders,* 5, 67-79.

Kahane, J. C. (1987). Connective tissue changes in the larynx and their effects on voice. *Journal of Voice,* 1, 27–30.

Ketelslagers, K., De Boldt, M. S., Wuyts, F. L., & Van de Heyning, P. (2007). Relevance of subglottic pressure in normal and dysphonic subjects. *European Archives of Oto-Rhino Laryngology,* 264, 519-523.

Klich, R.J., & Sabo, W. J. (1988). Intraoral pressure differences in various degrees of breathiness. *Folia Phoniatrica,* 40, 265-269.

Löfqvist, A., Carlborg, B., & Kitzing, P. (1982). Initial validation of an indirect measure of subglottic pressure during vowels. *Journal of Acoustic Society America,* 72, 633-635.

Miller, C. J. and Daniloff, R. (1993). Airflow measurements: theory and utility of findings. *Journal of Voice,* 7, 38–46.

Mittman, C., Edelman N. H., & Norris, A. H. (1965). Relationship between chest wall and pulmonary compliance with age. *Journal of Applied Physiology,* 20, 1211-1216.

Netsell, R., Lotz, W., & Shaughnessy, A. L. (1984). Laryngeal aerodynamics associated with selected voice disorders. *American Journal of Otolaryngology*, 5, 397-403.

Rajeev, P. (1995). *A normative data on aerodynamic parameters in normal adults*. Unpublished Master's dissertation, University of Mysore, Mysore.

Sharma, G., & Goodwin, J. (2006). Effect of aging on respiratory system physiology and immunology. *Clinical Interventions in Aging*, 1(3), 253-260.

Smitheran, J. R., & Hixon, T. (1981). A clinical method for estimating laryngeal airway resistance during vowel production. *Journal of Speech Hearing Disorders,* 46, 138-146.

Sperry, E. E., & Klitch, R. J. (1992). Speech breathing in senescent and younger women during oral reading. *Speech Hearing Research*, 35, 1246–1255.

Stathopoulos, E. T., & Sapienza, C. (1993). Respiratory and laryngeal function of women and men during vocal intensity variation. *Journal of Speech and Hearing Research,* 36, 64–75.

Weinrich, B., Salz, B., & Hughes, M. (2005). Aerodynamic measures: Normative data for children ages 6:0 to 10:11 years. *Journal of Voice*, 19, 326–339.

Yiu, E. M., Yuen, Y. M., Whitehill, T., & Winkworth, A. (2004). Reliability and applicability of aerodynamic measures in dysphonia assessment. *Clinical Linguistics and Phonetics,* 18, 463-478.

Zheng, Y. Q., Zhang, B. R., Su, W. Y., Gong, J., Yuan, M. Q., Ding, Y.L., & Rao, S. Q. (2012). Laryngeal aerodynamic analysis in assisting with the diagnosis of muscle tension dysphonia. Journal of Voice, 26 (2), 177-181.

Zraick, R.I., Smith-Olinde, L., & Shotts, L. L. (2012). Adult Normative Data for the KayPENTAX Phonatory Aerodynamic System Model 6600. *Journal of Voice,* 26 (2), 164-176.

Appendix-1

Mean, SD and range for laryngeal aerodynamic measures ESGP, MAFR, LAR, and LAC.

Laryngeal aerodynamic measures	Age range (n=38) (18-25 years)		Age range (n=39) (26-40 years)	
	Mean (±SD)	Range	Mean(±SD)	Range
ESGP (cm H_2O)	4.74 (±1.35)	2.89-9.13	5.68(±1.23)	4.00-9.04
MAFR* (L/s)	0.26(±0.14)	0.02-0.63	0.25(±0.12)	0.71-0.52
LAR* (cm H_2O/ L/s)	23.12(±12.93)	6.99-56.86	27.44(±15.29)	11.03-69.15
LAC (L/s/ cm H_2O)	0.05(±0.03)	0.00-0.14	0.04(±0.02)	0.01-0.09

*No age effect (p<0.05)

** Gender was not found have significant effect on these parameters at p<0.05 significance level, hence the presented normative is independent of gender.

PHONETIC CHARACTERISTICS OF VOWELS IN BABBLING

[1]Sreedevi N., [2]Jyothi S. & [3]Smitha K. Nair

Abstract

Children continually fascinate adults with their incredible daily developments. One of the most impressive accomplishments is the child's ability to produce speech sounds. In human speech, vowel is the sonority peak of a syllable and it is the most crucial element in human language. During babbling vowels exceed the number of consonants produced for most children. Vocalic development has been less extensively studied than consonant development, mainly because vocalic utterances are very difficult to transcribe reliably and thus not easy to arrive at a valid developmental profile. Therefore, recent studies on vowel development, especially in the first year, employ both perceptual transcription with high-quality recording and transcribing equipment and acoustic analysis. The purpose of the study is to examine the phonetic characteristics of vowels in 6 typically developing infants in the age range of 4 to 5 months from native Kannada speaking homes. Participant selection is based on the parent case history report. Each child is visited at home, in the fourth month of infant's age. Audio and video recording sessions of 30 minutes for all the infants are carried out in the presence of the mother using a digital video recorder (Sony Handy cam DCR DVD 908). The recorded data are transcribed phonetically using International Phonetic Alphabet (Broad phonetic transcription method). Inter judge-reliability of phonetic transcription is evaluated by two speech language pathologists for 10% of the selected samples. The transcribed vocalizations are then analyzed for their frequency of occurrences with respect to tongue height, tongue advancement and lip rounding. The qualitative and quantitative data obtained would help to gain an insight regarding what is normally expected of an infant at the early stage of communication development and aid the Speech Language Pathologists in making appropriate clinical decisions.

One of the most impressive accomplishments is the child's ability to produce speech sounds and the ability to combine those sounds to form words. The study of babbling has grown substantially in recent years and much is now known about the acquisition of speech and language in the early years of life. Although children do not produce speech until they are approximately one year old, the development of the ability to produce speech sounds begins in early infancy, and the important developments in speech sound production occur throughout the first year of life. Babbling is an important first phase of development towards adult speech production ability. It begins at a stage where consonant and vowel sequences conform to rhythmic patterns perceived as speech-like in timing (Oller, 1980).

Empirical studies demonstrate that vocal development in infancy follows an orderly sequence (Koopmans-van Beinum & van der Stelt, 1986). Stark (1980) proposed a five-level model in which infants progressed from reflexive sounds (e.g., cry and discomfort sounds) to cooing (i.e., the voluntary productions of comfort sounds in the velar area), to vocal play (i.e., sounds showing increased control of phonation and articulation), to reduplicated babbling (i.e. repeated production of canonical syllables such as /di/di/di/di/) to single words and nonreduplicated babbling (i.e., productions of phonetically varied, adult like syllables such as /dibu/dibu/). Knowledge of typical speech development is essential in order to identify the differences in early vocal development when a disorder is present (e.g. loss of hearing), and to understand when developmental processes are influenced by a second language. In human speech, vowel is the sonority peak of a syllable and it is the most crucial element in human language (Maddieson & Ladefoged, 1995). Vowels exceed the number of consonants during babbling for most children. Unfortunately, there is not an abundance of documented research examining vowel development during these first 12 months. Vowels have been less extensively investigated, because they are particularly difficult to transcribe reliably and, thus not easy to characterize. Lieberman (1980) reported inter-transcriber reliability of 73 percent for the vowels produced by children aged about 3 to 14 months. He used spectrographic analysis for a single child as a supplement to phonetic transcription and reported little change in average formant frequency values over the period investigated. However, the various vowels transcribed for four months showed considerable overlap in formant frequencies. In a study of 10 month old infants' vowel productions

[1]Reader in Speech Sciences, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: srij_01@yahoo.co.in, [2]Research Officer, AIISH, Mysore-06, Email: jyo.ammu@gmail.com & [3]Clinical Linguist, AIISH, Mysore-06, Email: krishnasmi@gmail.com

drawn from four linguistic communities-Arabic, Chinese, English, and French, De Boysson-Bardies, Sagart, Halle and Durand (1989) found that the categories of front-low and mid-central vowels accounted for the vast majority of vowels from all four groups. According to Irwin (1947, 1948), the vowels /ε, Λ, I/ were most prominent during first 2 months, followed by /æ, U, u, a, e, i/ and during the period of 2-5 months the vowels /ə, o/ emerged. He reported that vowels continue to outnumber consonants during this period. Several researchers have suggested that the quantity and the diversity of vocalizations do indeed play a role in later language development. An intensive study of this acquisition process is extremely important for the Speech-language pathologist since one of the primary responsibilities of the Speech-language pathologist is to distinguish normal from disordered phonological development in a particular child and to base treatment on that distinction. Speech-language pathologists, especially those in early intervention services, are often confronted with children who are still within the babbling stages of development. Therefore, knowledge of the babbling stages, that includes characteristics and approximate ages of occurrence, would be helpful in assessment and early intervention process. Lack of Indian studies in this domain provides the motivational rationale for the present study. Hence the aim of the present investigation was to study the phonetic characteristics of vowels in the babbling stage of 4-5 months old typically developing infants from native Kannada speaking homes.

Method

Participants: Six typically developing infants [3 males (M1, M2, and M3) and 3 females (F1, F2 and F3)] in the age range of 4-5 months from native Kannada speaking homes were considered in the study. It was ensured that all the participants had exposure only to Kannada language**.** Also the children did not have history of any medical, speech, language, hearing, cognitive or any other motor difficulties. The participants were selected after a parental interview and an informal assessment of age appropriate skills based on checklists (Developed by Department of Prevention of Communication Disorders (POCD), AIISH).
The participants selected belonged to middle socio-economic class.

Procedure: Each infant was visited at home during 4-5 months of infant's age. 30 minutes of audio and video recording was carried out when the infant was in a comfort state using a digital video recorder (Sony Handy cam DCR DVD 908). The recording was carried out in a quiet environment in a semi-structured manner where the experimenter was a passive observer. Parents were instructed to interact with the infant naturally. The parent-infant interaction and the use of toys were used as elicitation techniques.

Data analysis: The recorded data was edited to eliminate the parent's speech and the non-vegetative vocalizations (such as cries, burps, and coughs) to retain the infant's utterances which were transcribed phonetically using International Phonetic Alphabet (Broad phonetic transcription method). Inter judge-reliability of phonetic transcription was evaluated using point to point agreement by three transcribers (2 SLPs and a linguist) for 10% of the samples. The selected samples for each subject were analyzed according to the parameters under investigation after transcribing the required data.

Results and Discussion

The recorded data of 6 infants was phonetically transcribed using IPA (broad transcription method) for individual vowel types in the following categories and their descriptions are provided in Table 1.

1. Vowels classified according to tongue height – high, mid and low vowels.
2. Vowels classified according to tongue advancement – front, central and back vowels.
3. Vowels classified according to the duration of its production - short and long vowels.
4. Vowels classified according to lip rounding – rounded and unrounded vowels.
5. The frequency of occurrence of each of the individual vowel types for all the participants was established.

Table 1*: Description of vowels in Kannada*

	Short	Long
High front unrounded	/i/	/i:/
Mid front unrounded	/e/	/e:/
Low front unrounded	/æ/	/æ:/
Low central unrounded	/a/	/a:/
Mid central unrounded	/ə/	/ə:/
High mid central unrounded	/ε/	/ε:/
Mid back unrounded	/o/	/o:/
High back rounded	/u/	/u:/

Source: Upadhyaya (1972). Kannada Phonetic Reader. Volume 1 of CIIL phonetic reader series.

Note: /æ/, /ə/ and /ε/ occur primarily in loan words and in some rare instances in native Kannada words.

Mean values and standard deviations of the vowel types are classified according to tongue height and tongue advancement parameters and are presented in Table 2. Figure 1 represents the mean percentage of occurrence of vowels in all the six participants.

Table 2*: Mean of occurrence and standard deviations (in parenthesis) of vowels*

Vowels	Mean (SD)
[æ]	2.333 (2.732)
[æ:]	9.833 (9.641)
[ə]	10.33 (6.801)
[ə:]	15.5 (14.85)
[a]	1.666 (2.065)
[a:]	2.5 (2.880)
[i]	-
[i:]	-
[u]	-
[u:]	0.166 (0.408)
[e]	1.666 (2.338)
[e:]	19.16 (31.83)
[ɛ]	0.333 (0.816)
[ɛ:]	3.166 (4.215)
[o]	-
[o:]	-

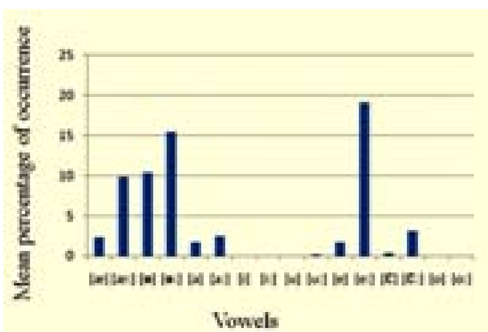

Figure 1: *Mean percentage of occurrence of vowels*

From Table 2 and Figure 1, it can be noted that overall, the mid-front long vowel [e:] and mid-central long vowel [ə:] dominated the utterances of all the infants followed by low-front long vowel [æ:] and mid-central short vowel [ə]. The occurrence of the low-front short vowel [æ], low-central short vowel [a] and mid-front short vowel [e] were comparatively low. On examining the developmental trend in babbling between the participants, the mid-front vowel [e], low-front vowel [æ] and mid-central vowel [ə] made their appearance more during this period of 4-5 months of age of the infants.

Vowels classified according to tongue height

According to tongue height dimension of the vowels, the frequency of occurrence of [e:] was more among the mid vowels. The low vowel [æ] dominated the utterances compared to the other low vowel [a]. The high back vowel [u] appeared in one participant (M3) and high front vowel [i] did not appear in this age group. This result is in agreement with the study of MacNeilage and Davis (1990) who reviewed studies of vowels in babbling in twenty-three infants reported a tendency for mid and low and front and central vowels to be preferred across languages. This apparent preference for 'lower left quadrant' vowels also appeared in the analysis of a large database produced by six English-learning infants (Davis & MacNeilage, 1995).

Vowels classified according to tongue advancement

According to tongue advancement dimension, reflecting on all the front vowels together, the vowel [æ, e] made more frequent appearances compared to the other front vowel [i]. The central vowel [ə] made predominant appearances than [a]. The back vowel [u] made its appearance in one participant (M3) in one instance and [o] did not appear in this age group. This finding is in agreement with the results of the study by Irwin and Curry (1941) where front vowel /ɛ/ represented 31.3% and back vowel /u/ consisted of 9% of all the vowels.

Vowels classified according to lip rounding

According to lip rounding dimension, unrounded vowels made predominant appearances [æ, e, ə]. The rounded vowel [u] was produced by one participant (M3) in only one instance and [o] did not appear during 4-5 months of age.

In the present study, the occurrence of vowels showed wide variability. According to the tongue height dimension, low vowel [æ] predominated in two participants (M1 and F3) and mid vowel [e] in one participant (F1). Variability in the production of vowels during babbling has been well documented in the literature. Davis and MacNeilage's (1995) longitudinal study with 6 infants (3 males, 3 females) from monolingual English-speaking homes revealed much individual variability in the use of vowels. According to the tongue height dimension, mid vowels, particularly [ə and e] predominated in 3 participants, while high vowels, particularly [u and i], appeared only in the remaining 3 participants. In relation to tongue advancement, front vowels, particularly [æ], predominated in 4 participants, and the mid vowels [e, ə], predominated in the remaining two. In the present study, few vowel transitions, diphthongs and VCV (Vowel-Consonant-Vowel) syllable shapes were also observed. Participants M1, M2, and M3 produced vowel transitions like [əæ], [əe]. Diphthongs [au] and [ai] were produced by M2 and F2 respectively. Aspirated like [e] and [ə] were produced by M2 in some instances. Few consonant syllable shapes like [əgə], [əgu] were produced by F3. Bilabial trill and glottal stop made their appearance in M3.

Conclusions

Babbling is an important milestone of early communication which can serve as a predictor of later language ability. It is also an important milestone in the development of articulation and phonological skills. Babbling lies at the juncture of pre-linguistic and linguistic phonological development. In the present study, an attempt was made to analyze the phonetic characteristics of vowels in typically developing infants from native Kannada speaking homes. The vowel repertoire during 4-5 months of infant's age mainly consisted of [æ, ə, a, e,]. The occurrence of high-front long vowel [e:] and mid-central long vowel [ə:] was consistently the highest across all the participants. The occurrence of the high-front vowel [i] and high-back vowel [u] were low in this age range and the mid-back vowel [o] did not appear in any of the infants. Overall, according to tongue height dimension, mid and low vowels dominated the utterances than high vowels. According to tongue advancement dimension, front and central vowels dominated utterances than back vowels. In lip rounding dimension, unrounded vowels dominated over rounded vowels. Considering vowel length, long vowels were more prevalent in the infant utterances than short vowels. The implication of this investigation is that qualitative and quantitative data obtained would help to gain an insight regarding what is normally expected of an infant at the early stage of communication development and aid the Speech Language Pathologists in making appropriate clinical decisions considering the fact that at present, communication rehabilitation services are sought for even infants younger than one year of age. However this study is confined only to the early vowel production of 4-5 month old infants from native Kannada speaking homes.

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References

Davis, B. L., & MacNeilage, P. F. (1995). The Articulatory Basis of Babbling. Journal of Speech and Hearing Research, 38, 1199-211.

De Boysson-Bardies, B., Sagart, L., Hallé, P. & Durand, C. (1986), Acoustic investigation of cross-linguistic variability in babbling. In B. Lindblom and R. Zetterström (Eds), Precursors of early speech. Wenner-Gren International Symposium. Series 44. New York, Stockton Press, 113-126.

Irwin, O. C. (1947). Infant speech: Consonantal sounds according to place of articulation. *Journal of Speech Disorders.* 12, 397–401.

Irwin, O. C. & Curry, T. (1941). Vowel elements in the crying vocalization of infants under ten days of age. *Child Development*. 12, 99.

Koopmans-van Beinum, F. J., & van der Stelt, J. M. (1986). Early stages in the development of speech movements. In B. Lindblom & R. Zetterstrom (Eds.), *Precursors of early speech*. New York: Stockton.

Lieberman. P (1980). On the development of vowel production in young children. Child Phonology: Volume 1, Production, ed. by G. H. Yeni-Komshian, J. F. Kavanagh, and C. A. Ferguson, 113-142. New York: Academic Press.

MacNeilage, P. F. & Davis, B. (1990). Acquisition of speech production: Frame, then content. In M. Jeannerod (ed.), Attention and performance XIII: Motor representation and control, 453–75. Hillsdale, NJ: Lawrence Erlbaum.

Maddieson, Ian, & Ladefoged, Peter. 1995. Sounds of the World's Languages. Oxford: Blackwell.

Oller, D. K. (1980). The emergence of the sounds of speech in infancy. In G. Yeni-Komshian, J. Kavanagh, & C. Ferguson (Eds.), *Child phonology: Vol. 1. Production* (pp. 93-112). New York: Academic Press.

Stark, R. E. (1980). Stages of speech development in the first year of life. In G. Yeni-Komshian, J. Kavanagh, & C. Ferguson (Eds.), *Child phonology: Vol. 1. Production* (pp. 73-90). New York: Academic Press.

Upadhyaya, U. P. (1972). *Kannada phonetic reader.* Mysore, India: CIIL.

PRE-POST COMPARISON OF STUTTERING AWARENESS PROGRAM AMONG PROSPECTIVE TEACHERS: A PRELIMINARY STUDY

[1]Geetha M. P., [2]Shwetha C., [3]Sangeetha M. & [4]Sheela S.

Abstract

As stuttering exists worldwide, among different culture/people, it is essential in identifying attitudes, concern, nature of problem in different cultural groups. The main objectives of the study are to identify effectiveness of sensitization program on stuttering immediately after program and also to determine the gender difference in attitude towards stuttering. A questionnaire was modified and adapted, and administered prior and after the sensitization program. The seven domains included in the questionnaire were myths/facts, attitude, causes, treatment, awareness, characteristics and occurrence of stuttering. Results indicated improved scores on few domains such as attitude, characteristics and treatment. Remaining domains such as myths/facts causes and occurrence of stuttering showed no significant difference prior and after the sensitization program on stuttering. Male participant's perception on stuttering was better compared to female participants on all domains except characteristics domain. Improved scores on few domains after awareness program suggested that awareness about stuttering was better after the sensitization program.

Key Words*: Sensitization program, Questionnaire, Teachers, Attitude.*

The successful communication takes place only when the information is exchanged smoothly between the speaker and the listener without any interruptions. Fluent speech has three dimensions or components - (i) continuous or smooth flow of speech, (ii) rate of information flow, & (iii) the effort of the speaker. Dysfluency means the disruption of smooth forward flow of the speech. Bloodstein (1987) defines stuttering as a disorder in which the fluency or "rhythm" of speech is disrupted by blockages or interruptions.

Stuttered speech is characterized by syllable prolongations and repetitions. In addition to their speech, stuttering individuals also deal with secondary behaviors such as head jerks, arm jerks, finger tapping, excessive eye-blinks, wrinkling of the forehead, lip bites, clavicular breathing, and involuntary arm, torso, and leg movements and emotions (Williams, 2006). The persons with stuttering experiences shame, guilt, embarrassment due to their inability to express their thoughts which in turn impacts their social life (Van Riper, 1971; Ginsberg, 2000; Kalinowski & Saltuklaroglu, 2006). Additionally, moderate–severe stuttering may induce negative emotional responses in listeners may alters the communication between the person who stutters and their listeners (Bloodstein, 1995; Guntupalli et al., 2006). If the listeners are strangers then persons who stutter often report negative emotional responses such as impatience, giggling, embarrassment, surprise, pity or laughter. These negative emotional responses may lead to developing the compensatory strategies such as avoidance of sounds, words, people and places.

When unnatural break (such as stuttering) is introduced in the natural flow of speech, the listener might show a startle reaction in response to the sudden aberrant stuttering behaviors. When listener observes an unexpected behavior, there may be a surprise or an illusionary threat response to the stimulus, but when this illusion disappears with the realization of no imminent threat, there is an emotional incongruity (Ramachandran 1998). Rosenberg and Curtiss (1954) noticed that when person who stutters exhibits stuttering behaviors, listeners became much less mobile, lost eye contact, and reduced their speech output. Several studies have shown that the attitude towards the individuals affected may be influenced by the awareness and knowledge of a given communication disorder.

Stereotyping is a misclassification scheme that is applied to individuals. These include quiet, secured, avoiding, fearful, unpleasant, nervous, and shy among others (Leahy, 1994; McGee, Kalinowsky, & Stuart, 1996). A variety of stakeholders have been found to report such stereotypes, including parents (Crowe & Cooper, 1977), teachers (Crowe & Cooper, 1977), employers (Hurst & Cooper, 1983), speech-language pathologists and speech- language pathology students (Cooper & Rustin, 1985; Leahy, 1994), the general public (Kalinowski,

[1]Speech Language Pathologist Grade 1, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: geethaslp@gmail.com, , [2]Clinical Supervisor, AIISH, Mysore-06, Email: cshwtha3@gmail.com, [3]Clinical Lecturer, AIISH, Mysore-06, Email: sangmahesh9@yahoo.co.in & [4]Research officer, AIISH, Mysore-06, Email: sheela.mslp@gmail.com

Armson, Stuart, & Lerman, 1993), as well as people who stutter themselves (Kalinowski, Lerman, & Watt, 1987). Negative stereotypes are extremely resistant to change, and have many harmful implications in the lives of people who stutter (Synder, 2001).

According to Williams (2006), many people who stutter feel that their speech often has a negative impact on performance evaluations, and leads to inaccurate judgements of their abilities. These negative stereotypes affect children as well. Children who stutters are often kept from being placed in leadership positions in the classroom, are viewed negatively by their teachers, and are prohibited to speak as often as their peers within the classroom. This may in turn affect academic progress and result in teasing within the school environment. Some even reported that they were told it was the reason they were not hired for a job. Hurst and Cooper (1983) confirm this speculation by stating that many employers agree that job opportunities are limited for those who stutter. In addition, negative stereotypes increase self-consciousness and worry within social situations, and cause people who stutter to avoid situations in which society expects them to fail (MacKinnon, Hall, & MacIntyre, 2007). Evidence also reveals that individuals who stutter often experience feelings of inadequacy, powerlessness, helplessness, hopelessness, and failure. Although these feelings may be a result of their inability to speak fluently, there is reason to believe that these feelings may be related to being placed in a category that is viewed as undesirable (Leahy, 1994). In addition, people who stutter often report that the reactions and attitudes of their listeners influence the severity of their stuttering (Klassen, 2001).

A 25-item, yes/no questionnaire was used by McDonald and Frick (1954), on the store clerks to assess their attitude towards persons with stuttering when they had conversation with them. The results revealed that listeners expressed sympathy, embarrassment, curiosity and surprise when talking to a person who stutters. Together these findings suggest that listeners generally appear to possess unfavorable perceptions towards individuals who stutter. Emerick (1960) assessed the knowledge and attitudes toward stuttering in 203 subjects based on the factors such as age, gender, years of education, knowledge about stuttering, number of people who stutter personally known, number of stuttering courses completed and possession of the Certificate of Clinical Competence in speech-language pathology towards the prediction of attitudes toward people who stutter, their parents, and the efficacy of therapy using the stuttering inventory. They found that individuals who possessed the Certificate of Clinical Competence were the most reliable predictor of attitude scores.

Crowe and Cooper (1977) developed the Parental Attitudes Toward Stuttering (PATS) Inventory and the Alabama Stuttering Knowledge (ASK) and administered on 50 parents of children with stuttering and 50 parents of children with no stuttering to investigate the parental attitudes and knowledge of stuttering. The test results indicated that the parents of children with no stuttering displayed more desirable attitudes toward stuttering and more accurate knowledge of stuttering than did the parents of children with stuttering. Crowe and Walton (1981) reported significant positive correlations between knowledge of stuttering and teacher attitudes in 100 elementary school teachers using the Teacher Attitudes Toward Stuttering (TAT) Inventory (Crowe & Walton, 1978) and there was also significant negative correlations between teacher attitudes/knowledge of stuttering and the presence of a stuttering child in the classroom. Similarly, Yeakle and Cooper (1986) used the Teachers' Perceptions of Stuttering Inventory (TPSI) to assess the attitudes of 521 teachers in the Tuscaloosa, Alabama City School (82% of the teacher population) toward stuttering. The TPSI consists of five teacher identification questions and 10 attitudinal statements where the teachers were asked to indicate their strength of agreement. They found that significant number of teachers had unsupported beliefs regarding the etiology of stuttering and the personality characteristics of stutterers. Therefore, they concluded that the teachers who had course work in speech disorders and experience with stutterers had more realistic and demanding attitudes toward stutterers in the classroom situation.

A study by Lass, Ruscello, Schmitt, Pannbaker et al. (1992,1994) considered 42 school administrators in Alabama, Louisiana, Texas, and West Virginia, provided a questionnaire asking respondents to describe four hypothetical stutterers (a female child, male child, female adult, and male adult). The majority of reported adjectives (related to personality, physical appearance, intelligence, speech behavior and others) were negative stereotypical personality traits, indicating perceptions of people who stutter similar to perceptions of teachers, special educators, and speech-language pathologists. A total of 197 adjectives were obtained by school administrators describing 72.6% were negative in nature, 19.8% were positive and 7.6% were neutral towards PWS.

Similarly, 287 adjectives were obtained by elementary and secondary school teachers to describe PWS of which 66.9% were negative in nature, 20.2% were positive and 12.9% were neutral.

A study conducted by Irani and Gabel (2008), assessed the attitudes toward people who stutter (PWS) of 178 school teachers' (kindergarten to 12^{th} grade; all 50 states of USA) based on level of experience with PWS and their previous coursework on stuttering. A 14-item semantic differential scale was used to measure their attitudes towards PWS as compared to fluent speakers. The results indicated that the teachers had positive attitudes towards both PWS and fluent speakers. The semantic differential scale scores indicated that for three items, PWS were judged more positively. But educational and experiential factors were found to have no significant effect on the teachers' attitudes toward PWS.

An Indian study by Chandrabose, Louis, Pushpavathi and Raoof (2010) made an attempt to explore the awareness and attitude of prospective teachers towards stuttering in Mysore city, conducted as a part of International Stuttering Awareness Day. The attitudes of 64 educators towards stuttering were studied using the questionnaire developed with few statements adapted from Public Opinion Survey of Human Attributes (POSHA -E) consisting of eight domains such as nature, concern, attitude, causes, treatment, awareness, characteristics and occurrence of stuttering. The results indicated that their awareness on stuttering was less on some domains but also reflected positive attitude on some other domains.

Purpose of the study: Even though, the majority of the population has knowledge about stuttering, the awareness appears to be limited on certain aspects. Depending on the factors such as gender, age, educational level and occupation, the knowledge differs among participants. Several studies have focused mainly on the attitude towards stuttering but not on the effectiveness of the sensitization program. Hence this present study is aimed to compare the effectiveness of sensitization program with respect to pre- and post among prospective teachers and also to find out the difference in opinion among the male and female participants.

Method

The current study has been carried out in 4 steps:
Step 1: Preparation of questionnaire
Step 2: Administration of the developed questionnaire before sensitization program (Pre)
Step 3: Lecture on 'Sensitization program on stuttering'
Step 4: Re-administration of questionnaire soon after the sensitization program (Post)

Step 1: A questionnaire was prepared by qualified Speech Language Pathologist having experience in assessment and management in dealing with fluency disorders. The Public Opinion Survey of Human Attributes (POSHA-E) questionnaire of St.Louis (2005) adapted by Chandrabose, Louis, Pushpavathi and Raoof (2010) was modified and used. POSHA-E is the first prototype of questionnaire was developed by St. Louis, Andrade, Georgieva, and Troudt, (2005) to measure the attitude towards stuttering. It has been translated in several languages and used worldwide. Like most other measures of attitudes, the POSHA-E samples a variety of beliefs, reactions, behaviors, and emotions that would identify societal ignorance, stigma, and/or discrimination (e.g., Hulit & Wertz, 1994; Blood et al., 2003; Gabel, Blood, Tellis & Althouse, 2004; Klein & Hood, 2004). In this study, the modified POSHA-E is intends to elicit the attitudes and other human attributes towards stuttering.

The adapted questionnaire by Chandrabose et al (2010) consisted of 8 domains (nature, concern, attitude, causes, treatment, awareness, characteristics and occurrence of stuttering) in Kannada language. However, in the present study the questionnaire was condensed to 7 domains, where statements related to nature and concerns of the previous questionnaire were considered under the domain of myths/facts.

Step 2 and 4: Administration of questionnaire prior to and after the sensitization program on stuttering (Pre and Post):

Participants: A total of 103 trainee teachers (69 males and 34 females), who were native Kannada speakers, from BS.Ed, and D.Ed, colleges from Mysore city, participated in the present study. The participants were in the age range of 19-22 years. None of the teachers had a history of stuttering or hearing loss or neurological disorders. And none of the participants had attended sensitization program on stuttering before.

Procedure

The questionnaire was administered twice i.e. before and after sensitization program. Before the commencement of sensitization program, all participants were asked to complete the pre-test questionnaire for each statement using 'Yes', and 'No' to check the awareness level of the teachers about stuttering and were collected back. Once it was collected, the sensitization program was conducted for half a day. The same questionnaire was administered as post test after half an hour of the conclusion of the program, to evaluate the participant's ability.

Step 3: Lecture on the sensitization program

The program consisted of five consecutive sessions, each lasting for 45 minutes; wherein half an hour refreshment break was arranged. The participants were oriented on the following topics- Introduction to fluency, Fluency disorders: an overview, Myths/facts about stuttering, Role of teachers in identification of stuttering, Protecting and promoting for persons with stuttering.

Scoring: For scoring purpose score of "1" was allotted to answer "yes" and score of "0" was allotted to answer "no". The scores were tabulated depending on the number of correct answers separately for both pre and post test.

Statistical analysis: To check Pre-post and gender difference within each domain SPSS (PASW) statistical analysis software version 18 was employed.

Results and Discussion

The questionnaire was collected prior to and after the sensitization program on stuttering from the 103 trainee teachers (69 males and 34 females) to investigate any changes after the sensitization program by a comparison in seven domains. Out of seven domains, there was significant change in the domains of attitude, treatment and characteristics. The remaining domains such as facts/myths, causes, and occurrence did not show any significant difference. In the last domain i.e., 'awareness', out of 12, 10 analyzed statements showed significant differences at the post test scores.

1) Pre-post score comparison across six domains

Descriptive statistics and Paired t-test has been used to check the mean difference between pre and post test scores. The mean value and standard deviation (SD) of the domains-myths/ facts, attitude, causes, treatment, characteristics and occurrence of stuttering is given in the table 1. The results showed there was significant improvement in the mean score at post test in the following domains i.e., attitude, treatment and characteristics respectively. Domains of attitude and treatment showed highly significant difference between pre and post test scores which is also depicted in the figure 1. This indicates that all participants might require orientation on the attitude, treatment and characteristics of stuttering effectively. In other words, the participants may be much aware of the facts about the stuttering (statements related to intelligence, self-confidence, competence, behavior, anxiety etc), what might cause stuttering (statements related to stuttering causes due to heredity, bacteria/virus, imitation, practice effect, psychological and neurological related issues) and the occurrence of stuttering (statements were related to the age of onset of stuttering and variation across gender), so that there was no significant difference in the pre-post comparison.

Table 1: *Mean and SD of the pre-post test comparison across domains*

Domains	Phases	Mean	S.D	Sig.
Facts/myths	Pre	10.16	2.20	.085
	post	11.63	1.66	
Attitude	Pre	7.84	1.36	.000*
	post	8.22	1.04	
Causes	Pre	4.41	1.58	.107
	post	6.13	1.03	
Treatment	Pre	4.99	1.50	.000*
	post	6.33	1.22	
Characteristics	Pre	5.36	2.10	.006*
	post	7.10	1.65	
Occurrence of stuttering	Pre	5.81	2.73	.073
	post	8.37	2.19	

*(*indicates significant difference)*

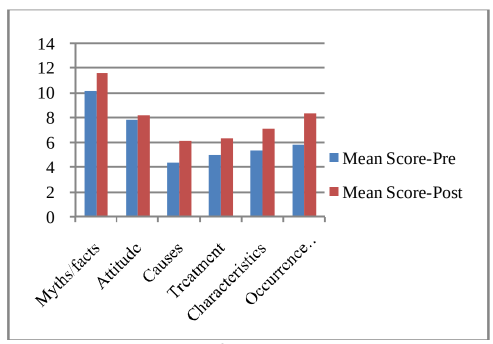


Figure 1: *Mean score of the pre-post test comparison across domains*

In this study, the negative attitudes towards stuttering such as sympathetic or losing patience or making fun etc at the pre test score had changed to positive at the post test score, after the sensitization program. A similar findings investigated by Ramachandran (1998) suggests that after knowing about the stuttering, the listeners perception had changed towards PWS. Hence, to change the listener's reactions or attitude towards stuttering have been considered an important factor from many decades.

In the domain of treatment, statements were mainly focused on whether PWS are treated by

Doctors, Speech language pathologist, Psychologist, Priest, Nurse, Teachers, Family members etc. Before the sensitization program, most of the participants answered that PWS are treated by Doctors and Priest. But after the sensitization program, most of the participant's opinion had changed to that they were treated by SLP's. And their opinion has changed that even teachers and family members are also involved as team members in treating PWS.

2) Pre-post scores comparison of gender across six domains

Independent sample t test has been performed to find gender difference across domains. Mean scores and SD are given in table 2, figures 2 and 3 respectively. During the pre test phase, male participants performed significantly better across all domains. There was statistically significant difference between male and female participants for domains such as attitude, causes, treatment, and occurrence of stuttering. Even though significant difference was not found for domains of facts/myths and characteristics but mean scores were better for male participants. Hence results revealed better performance by male participants than female participants before sensitization program. This indicates, male participants had better knowledge and good exposure about stuttering than female participants.

During the post test phase, both male and female participants could perform better across all domains except the domain of characteristics. Surprisingly improved scores were obtained by female participants in characteristic domain at post test scores. Improved scores across all domains for both participants indicate knowledge about stuttering increased after sensitization program. Overall results suggested improved scores for post test compared to pre test in both male and female participants. The improved scores also indicate the short term exposure to stuttering was better across gender group at post test. A check on the long term effects are further required.

Table 2*: Mean and SD of the pre-post test comparison across gender (*indicates significant difference)*

Domains	Phase	Gender	N	Mean	SD	df	Sig. (2-tailed)
Facts/myths	pre	Male	69	10.46	2.10	101	.042
		Female	34	9.53	2.28		
	post	Male	69	11.65	1.70	101	.856
		Female	34	11.59	1.61		
Attitude	pre	Male	69	8.20	1.10	101	.000*
		Female	34	7.12	1.55		
	post	Male	69	8.35	.85	101	.086
		Female	34	7.97	1.33		
Causes	pre	Male	69	4.78	1.49	101	.000*
		Female	34	3.65	1.49		
	post	Male	69	6.06	1.06	101	.343
		Female	34	6.26	.96		
Treatment	pre	Male	69	5.33	1.32	101	.001*
		Female	34	4.29	1.62		
	post	Male	69	6.46	1.19	101	.115
		Female	34	6.06	1.25		
Characteristics	pre	Male	69	5.61	2.00	101	.087
		Female	34	4.85	2.25		
	post	Male	69	6.83	1.79	101	.017*
		Female	34	7.65	1.17		
Occurrence of stuttering	pre	Male	69	6.58	2.34	101	.000*
		Female	34	4.24	2.82		
	post	Male	69	8.49	2.34	101	.417
		Female	34	8.12	1.85		

3) Pre-post scores comparison in the domain of awareness (7^{th} domain)

Overall pre-post scores comparison has been checked for other six domains. In this domain pre-post scores comparison is done across 12 statements. The statements are about self experience, contact with stutterers, family/friends famous personalities, TV/radio, newspaper/ through books, internet, at school, Doctor/nurse, cinema, others and I don't know. To find pre-post comparison Mcnemars statistical analysis has been performed. Mean scores and SD are given in table 3. It is interesting to know how all participants had gained knowledge about stuttering, whether it is from self experience or history of contact with stutterers or through TV/Radio or from famous personalities etc. It is also interesting to know whether knowledge about stuttering is remained same or changed at post score level i.e., number of participants saying 'yes' is same or different for both pre-post scores.

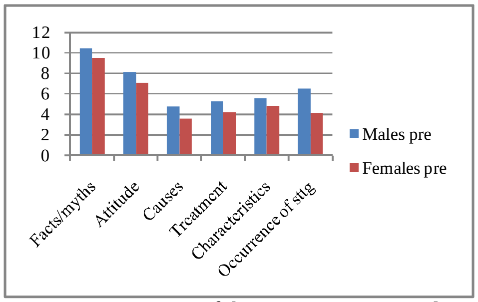


Figure 2: *Mean score of the pre test across gender*

There was significant difference for the statements such as contact with stutterers, family/friends, TV/ Radio, newspaper/through books, internet, at school, Doctor/Nurse, cinema, others, except for the statements such as self experience and famous personalities. The results suggested number of participants saying 'yes' in the post test phase had changed compared to pre test scores. This indicates during pre test, less number of participants had answered that they know about stuttering.

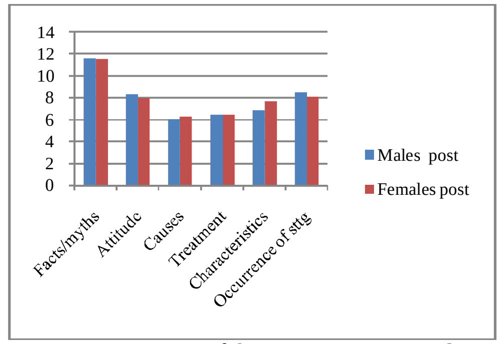


Figure 3*: Mean score of the post test across gender*

Improved scores among participants in the post test indicate even though they have little knowledge about stuttering, they understood the concept much better after the sensitization program. During the pre test phase most of the participants had answered 'yes' to the statement 12 ('I don't know'). This means if participant's answered the statements other than statement 12, indicate that they had knowledge about stuttering previously. Majority of participants answered 'yes' to this statement also could be because they had not read the statement properly prior to sensitization program.

Table 3: *Mean and SD of the pre-post test comparison for awareness domain (*indicates significant difference)*

Statements	Phase	Response	Post test yes	Post test no	P value
Self experience	pre	yes	53	16	1.000
		no	15	19	
Contact with stutterers	pre	yes	12	22	.004*
		no	6	63	
Family/friends	pre	yes	18	31	.000*
		no	7	47	
Famous personalities	pre	yes	47	18	.265
		no	11	27	
TV/Radio	pre	yes	15	25	.001*
		no	6	57	
News paper/Books	pre	yes	26	31	.000*
		no	6	40	
Internet	pre	yes	54	23	.005*
		no	7	18	
School	pre	yes	10	31	.001*
		no	9	53	
Doctor/Nurse	pre	yes	24	29	.020*
		no	13	37	
Cinema	pre	yes	16	35	.000*
		no	7	45	
Others	pre	yes	19	40	.000*
		no	3	41	
I don't know	pre	yes	69	6	.015*
		No	19	9	

During post test phase number of participants saying 'yes' to the statement 12 (I don't know) drastically reduced compared to pre test phase. In other words, during post test phase most of the participants answered 'no' to statement 12 might be the effect sensitization program.

Community plays a major role in building awareness on various communication disorders. Teachers are one of the important key personnel to work in the community. Hence, such sensitization programs will enable the teachers to understand about each condition and to suggest better health care and rehabilitation services.

Conclusions

The current study aimed to investigate short-term effect of sensitization program among prospective trainee teachers at Mysore city and also estimated the gender difference on all domains. The sensitization program consisted of five consecutive sessions and each lasted for 45 min. The participants were oriented on Introduction to fluency, Fluency disorders: an overview, Myths/facts about stuttering, Role of teachers in identification of stuttering, Protecting and promoting for persons with stuttering. A questionnaire was administered prior and after the sensitization program. The results indicated improved scores on some domains such as attitude, characteristics and treatment. Remaining domains such as myths/facts, causes and occurrence of stuttering showed no significant difference prior and after the sensitization program on stuttering. Male participants performed better compared to female participants on all domains except characteristics domain. This increased percent scores after awareness program suggested that awareness about stuttering was better after the sensitization program. Such programs can decrease the risk of stuttering severity and also relapse. Only a short-term effect has been checked, long-term effects and its practice in daily life needs to be evaluated.

References

Blood, G. W., Blood, I. M., Tellis, G. M., & Gabel, R. M. (2003). A preliminary study of self-esteem, stigma, and disclosure in adolescents who stutter. *Journal of Fluency Disorders, 28*, 143-159.

Bloodstein, O. (1987). *A handbook on stuttering*. Chicago, Illinois: The National Easter Seal Society.

Bloodstein, O. (1995). *A handbook of stuttering*. London: Chapman & Hall.

Chandrabose, J.G., Louis, K.O.S., Pushpavathi, M. & Raoof, S. (2010). Awareness of stuttering among prospective teachers of Mysore. *Journal of All India Institute of Speech Hearing,* Vol.29 (2).

Cooper, E.B. & Rustin, L. (1985). Clinician attitudes toward stuttering in the United States and Great Britain: A cross-cultural study. *Journal of Fluency Disorders, 10*, 1-17.

Crowe, T. A. & Cooper, E. B. (1977). Parental attitudes toward and knowledge of stuttering. *Journal of Communication Disorders, 10*, 434-357.

Crowe, T. A. & Walton, J. H. (1978). *Teacher attitudes toward stuttering inventory*. The University of Mississippi, Department of Communicative Disorders.

Crowe, T. A. & Walton, J. H. (1981). Teacher attitudes toward stuttering. *Journal of Fluency Disorders, 6*, 163–174.

Emerick, L.L. (1960). Extensional definition and attitude toward stuttering. *Journal of Speech and Hearing Research*, 3, 181- 186.

Ginsberg, A. P. (2000). Shame, self-consciousness, and locus of control in people who stutter. *Journal of Genetic Psychology, 161,* 389–399.

Gabel, R.M., Blood, G.W., Tellis, G.M. & Althouse, M.T. (2004). Measuring role entrapment of people who stutter. *Journal of Fluency Disorders, Vol29 (1)*, 27–49.

Guntupalli, V. K., Kalinowski, J., Nanjudeswaran, C., Saltuklaroglu, T. & Everhart, D. E. (2006). Psychophysiological responses of adults who do not stutter while listening to stuttering. *International journal of psychophysiology, 62*, 1-8.

Hurst, M.I. & Cooper, E.B. (1983). Employer attitudes toward stuttering. *Journal of Fluency Disorders, 8*, 13-27.

Irani, F. & Gabel, R (2008). Schoolteachers' Attitudes Towards People Who Stutter: Results of a Mail Survey. *Canadian Journal of Speech-Language Pathology and Audiology - Vol. 32, No. 3*, 129-134.

Kalinowski, J. and Saltuklaroglu, T. (2006). Stuttering (San Diego, CA: Plural).

Kalinowski, J.S., Armson, J., Stuart, A. & Lerman, J.W. (1993). Speech clinicians' and the general public's perceptions of self and stutterers. *Journal of Speech-Language Pathology and Audiology, 17*, 79-85.

Kalinowski, J.S., Lerman, J.W. & Watt, J. (1987). A preliminary examination of the perceptions of self and others in stutterers and non-stutterers. *Journal of Fluency Disorders, 12*, 317-331.

Klassen, T.R. (2001). Social distance and the negative stereotype of people who stutter. *Journal of Speech-Language Pathology and Audiology, 26*(2), 90-99.

Klein, J & Hood, S. (2004). The impact of stuttering on employment opportunities and job performance. *Journal of Fluency Disorders*, 29, 255-273.

Lass, N. J., Ruscello, D. M., Pannbacker, M., Schmitt, J. F., Kiser, A. M., Mussa, A. M., et al. (1994). School administrators' perceptions of people who stutter. *Language, Speech, and Hearing Services in Schools, 25*, 90-93.

Lass, N. J., Ruscello, D. M., Schmitt, J. F., Pannbacker, M. D., Orlando, M. B. & Dead, K. A., et al. (1992).Teachers' perceptions of stutterers. *Language, Speech, and Hearing Services in Schools, 23,* 78-81.

Leahy, M.M. (1994). Attempting to ameliorate student therapists' negative stereotype of the stutterer. *European Journal of Disorders of Communication, 29,* 39-49.

MacKinnon, S.P., Hall, S. & MacIntyre, P.D. (2007). Origins of the stuttering stereotype: Stereotype formation through anchoring adjustment. *Journal of Fluency Disorders, 32*, 297-309.

McDonald, E. T. and Frick, J. V. (1954). Store clerks' reaction to stuttering. *Journal of Speech and Hearing Disorders, 19*, 306–311.

McGee, L., Kalinowsky, J. & Stuart, A. (1996). Effects of a videotape documentary on high school students' perceptions of a high school male who stutters. *Journal of Speech-Language Pathology and Audiology, 20*(4), 240-246.

Ramachandran, V. S. (1998). Phantoms in the Brain: Probing the Mysteries of the Human Mind (New York, NY:William Morrow).

Rosenberg, S. & Curtiss, J. (1954). The effect of stuttering on the behaviour of the listener. *Journal of Abnormal and Social Psychology, 49*, 355–361.

St. Louis. (2005). cited in Chandrabose, J.G., Louis, K.O.S., Pushpavathi, M. & Raoof, S. (2010). Awareness of stuttering among prospective teachers of Mysore. *Journal of All India Institute of Speech Hearing,* Vol.29 (2).

Synder, G.J. (2001). Exploratory research in the measurement and modification of attitudes toward stuttering. *Journal of Fluency Disorders, 26*, 149-160.

Van Riper, C. (1971). The *Nature of Stuttering*. Englewood Cliffs, N. J.: Prentice-Hall.

Williams, D.F. (2006). *Stuttering recovery: Personal and empirical perspectives.* New Jersey: Lawrence Erlbaum Associates, Publishers.

Yeakle, M. K., & Cooper, E. B. (1986). Teacher Perceptions of Stuttering. *Journal of Fluency Disorders, 11*, 345-359.

SOME TEMPORAL CHARACTERISTICS OF SPEECH OF CHILDREN WITH UNOPERATED CLEFT LIP AND PALATE

[1]Gopi Sankar R. & [2]Pushpavathi M.

Abstract

Analysis of speech of individuals with cleft palate provides an insight to understand the physiology of CLP speech. The present study was aimed to investigate some temporal characteristics of speech in individuals with unilateral unoperated cleft palate and to compare with typically developing children (non-cleft. A total of 20 children were divided into two different groups ten in each group. Speech stimuli consisted of sixteen bisyllabic meaningful Kannada words loaded with target phonemes combined with consonants in CVCV combination (e.g. /pata/, /bada/ etc) in initial and medial positions. Participants were asked to repeat the words thrice clearly Vowel duration, closure duration and total duration were analyzed using PRAAT software version 5.1.27. The results revealed that vowel duration, closure duration and total duration in children with unoperated cleft palate was found to be longer when compared to that of the control group. The results also indicated significant difference across the group in all the three parameters studied.

Key words*:* *vowel duration, closure duration and total duration, acoustic analysis, cleft palate.*

Communication is vital for both biological and social existence. Man's most distinct attribute is the ability to communicate by means of visible and audible codes. Human communication depends on a number of elements of which hearing, vision, cognition and normal oral structures are of prime importance. But many birth defects produce gross physical deformities that hamper the normal communication process. Cleft lip and palate (CLP) is one of the most frequently occurring birth defect.

The incidence of cleft lip and palate in India is estimated approximately one in 781 live births (Raju, 2000). It is also estimated that every year nearly 36,000 children with cleft palate are born in India. Tata Institute of Social Sciences conducted a survey, which revealed that only 25% of the individuals with cleft palate have undergone surgery and these individuals were predominantly from districts with higher socioeconomic status. This indicates that majority of the clients from rural areas or lower socio-economic status lack the awareness of the condition and facilities related to intervention of the condition. While surgical repair often takes care of normalizing the appearance in CLP, debilitating speech disorders frequently persist in these individuals with CLP. Speech is considered as one of the primary outcome measures of CLP management and yet its measurement is elusive and challenging for speech-language pathologists. Despite the challenges, there are no common consensuses for speech assessment and measurement approaches for CLP. Forner (1983) spectrographically analyzed the utterances of fifteen children with congenital cleft palate in the age range of 5 to 6 years with varying degrees of hypernasality and compared with fifteen normal children. The stimuli consisted of five consonants nonsense syllables using /p/, /t/, /k/, /tf/ /s/. The stopgap of the plosives and affricate consonants was found to be the most deviant individual acoustic segment.

Vasanthi (2001) studied a few spectral and temporal parameters of speech in two individuals with repaired cleft lip and palate and compared with that of normal adults. She found that, in the first subject, terminal frequency F2 (TF_2) was found to be lower than normals. The frication duration and affrication duration were found to be shorter in individuals with cleft palate. In the second subject, she found omission of initial plosive consonant in words. She reported that, the duration of the following vowel was increased to keep the syllable duration constant. The VOT was found to be longer for unvoiced stops. For plosives, burst duration was not clear and lower F_2 was observed in both speakers. Casal et al (2002) studied the speech of twenty-two children with repaired cleft lip and palate and matched with twenty-two non-cleft children spectrographically. They used Spanish vocalic stimuli /a/, /i/, /u/, /e/, /o/, stop consonants /p/, /t/, /k/ and nasal stimuli /m/. They analyzed first, second formant, burst, voice onset time and duration. Results revealed there was significant difference between the control group and cleft palate group in the first formant of /e/ and in the frequency of the /t/ burst. The results also showed significant difference in the second

[1]Research officer, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email:sankaj2002@gmail.com & [2]Professor in Speech Pathology, AIISH, Mysore-06, Email: pushpa19@yahoo.co.in

formant of vocalic stimuli /a/, in the first formant of /o / and in the second formant of /o / across groups. Their results also indicated significant influence of the cleft lip or its repair on lip rounding for /o/ and /u/. In addition, the difference in tongue position was also attributed as responsible for the differences seen with /a/ and /e/.

Chen, Yang, Wu, Zang, and Wang (2005) have studied acoustic features of the consonant of sixty six individuals who underwent with post-palatoplasty velopharyngeal incompetence (VPI) with that of the normals. The speech stimuli consisted of /da/, /bo/, /ge/, /ji/, /ku/and /qu/ syllables were recorded and analyzed using computerized speech lab (CSL). They analyzed for duration of syllable (Dur), duration of the consonants (CD) and duration of the vowels (VD), voice onset time (VOT), first concentrated frequency of the consonants (F1), second and third concentrated frequency of the consonants (F2) and (F3). They found that significant difference in all the parameters across the group.

Gaylord and Zajac (2006) aimed to analyze the temporal characteristics in children with varying levels of velopharyngeal dysfunction. They considered speech stimuli consisted of ten /ta/ and /da/ phrases mainly consisting of alveolar stops. Stop gap and voice onset time were analyzed using CSL. Stop gap for /t/ was around 142.4 msec and for /d/ was around 153.7 msec. They found that stop gap duration decreased as level of VPD increased in English during production of aspirated. They hypothesized that this may have been a strategy adapted by the child in an effort to minimize the presence of nasal air emission.

Subramaniyam, Savitha and Biji (2011) studied to identify the distribution of glottal stops in individuals with repaired unilateral cleft lip and palate across different voiceless stop consonants in Tamil language. They found following rank order /k/ followed by /t/, /th/and /p/. Based on the wave form pattern they have sub classified in class A and class B glottal stops. In class A glottal stops wave form showed simultaneous voicing without release burst. In class B glottal stop wave form showed lag voicing with release burst. Closure duration for class A glottal stop was reported to be longer (259.4 msec) compared to that of normal subjects. Closure duration for class B glottal stop was reported to be longer (260.4 msec) compared to that of normal subjects. Burst duration of class B glottal stop was 7.3msec) within the range of normal burst duration of the stop consonants.

To summarize, there are very few studies on acoustic analysis of unoperated cleft palate speech. As a part of acoustic analysis, most of the studies are limited only to study the formant frequencies of vowels in individuals with cleft palate. However, there are no studies, which provide insight on detailed acoustic analyses of temporal characteristics of unoperated cleft palate speech. Hence, there is a need to study the temporal characteristics of speech in individuals with unoperated CLP.

The aim of the present study was to investigate, and compare the Vowel duration, Closure duration and Total duration among typically developing children (TDC) and children with unoperated cleft palate.

Method

Participants: Participants for the present study included two groups- Group I consisted of ten typically developing children (TDC) with normal oro-facial structures (normal/control group) and group II consisted of ten children with unilateral unoperated cleft palate (UnCP) (clinical/experimental group)details of the participants is given in table 1.

Table 1: *Details of the Subjects*

Subject No	Children with unrepaired cleft palate group	
	Age/gender	Diagnosis
1	7/F	Cleft of hard and soft palate
2	14/F	Cleft of soft palate
3	6/F	Cleft of hard and soft palate
4	5/F	Submucous cleft palate
5	6/F	Cleft of soft palate
6	5/M	Submucous cleft
7	6/M	Cleft of hard and soft palate
8	9/M	Cleft of soft palate
9	14/M	Submucous cleft palate
10	7/M	Submucous cleft palate

In which, 3 children had unrepaired hard and soft palate, 4 children had submucous cleft and 3 had cleft of the soft palate. All the participants were native speakers of Kannada language and they were in the age range of 5 -14 years. The mean age was around 8.7 years. Control group was screened using WHO ten disability checklists (Singhi, Kumar, Malhi & Kumar, 2007) for sensory and motor development.

Stimuli & Procedure: Speech stimuli consisted of eight bisyllabic meaningful Kannada words loaded with stop consonants (/p/, /ʈ/, /t/, /k/, /b/, /ɖ/, /d/and /g/). Stop consonants in the initial position followed by short vowel/a/ and those in the medial positions preceded by low mid open vowel /a:/ in CVCV combination (e.g. /pata/, /bada/, /a:ta/ etc). Participants were asked to repeat the words thrice clearly. The data was recorded using PRAAT software version 5.1.27(Boersma & Weenink, 2010) which was installed in the computer for both the groups. To confirm that the individuals with cleft palate uttered the target word, these words were given to Speech language pathologist who is experienced in analyzing cleft palate speech. The judge was asked to identify whether the subject was attempted to utter the target words correctly. The identified samples were considered for further acoustic analysis.

Acoustical Data Analysis

Vowel duration (VD), Closure duration (CD), Total duration (TD) and Voice onset time (VOT) were analyzed using the PRAAT software version 5.1.27 (Boersma & Weenink, 2010). Both spectrogram and wave form was used to analyze the sound segment durations. Each word was displayed on a broadband spectrogram with the pre emphasis factor of '0.80'. The analysis size and bandwidth was set to 100 points and 160 Hz hamming window was used. Spectrogram displayed using monochrome (black and white) in the linear scale. In reference to spectrographic analysis, temporal parameters measured using cursor as follows,

- ***Vowel duration (VD):*** It is the time difference between the onset and offset of the vowel.

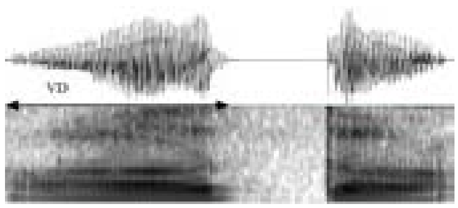


Figure 1: *Signal and Spectrogram of the word /a:ʈa/ (Vowel duration (VD)*

- **Closure *duration (CD):*** It is the time difference between the onset of the closure and the articulatory release in the production of a word-medial stop.

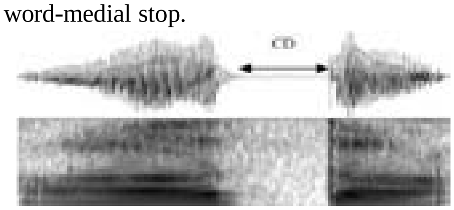


Figure 2: *Signal and Spectrogram of the word /a: ʈa/ (Closure duration (CD)*

- *Total duration (TD):* It is the time difference between the onset of the closure of stop consonants to the onset of the following vowel in word-medial position.

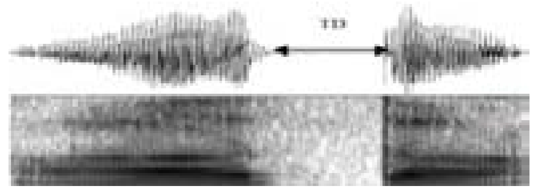


Figure 3: *Signal and Spectrogram of the word /a:ʈ a/ (Total duration (TD)*

Statistical analysis: Analyzed data was subjected to statistical analysis using SPSS 17.0 version. Non parametric statistics and Mann-Whitney Test was used to analyze the data.

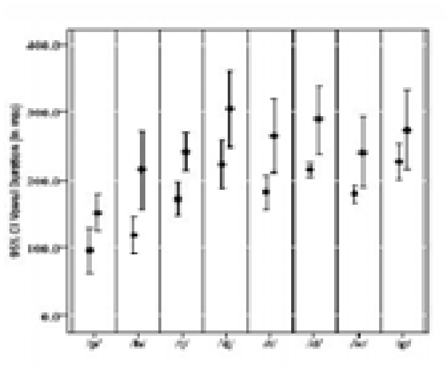
Results and Discussion

The aim of the present study was to study the temporal characteristics of speech in individuals with unilateral unoperated cleft palate conditions and to compare with typically developing children (non-cleft). Descriptive statistics was calculated for both groups based on the analyzed sample data.

Vowel duration (VD): Vowel duration was analyzed from the spectrogram. Table 2 shows the mean, SD and mod Z value for vowel duration for both normal and unoperated CP. It is evident that vowel duration for children with unoperated group was found to be longer when compared to that of the children with control group. Vowel duration was longer for voiced consonants compared to voiceless which was seen for all the stop consonants. Form the table it is evident that the vowel duration increased from /p/ (Normal 96.3msec, UnCP 152.2msec) to /g/ (Normal 227.5msec, UnCLP 274.1msec) same trend was observed for both groups.

Table 2: *Mean, SD and Mod Z value for Vowel Duration (VD) across the group*

VD	Normal		UnCP		Mod Z value	p value
	Mean	SD	Mean	SD		
/p/	98.4	47.1	153.4	37.3	2.34	<0.05
/b/	121.3	38.2	217.8	81	2.72	<0.001
/ʈ/	176.4	34.9	245.4	40.1	2.87	<0.001
/ɖ/	223.1	50.9	305.4	79.9	2.34	<0.05
/t/	182.5	35	265.7	76.2	3.02	<0.001
/d/	215.5	13.3	289.8	64.8	3.18	<0.001
/k/	179.9	16.7	241.4	72.2	3.09	<0.001
/g/	227.5	35.9	274.1	82	1.20	>0.05



Graph 1: *Vowel duration for normal and Unoperated CP group*

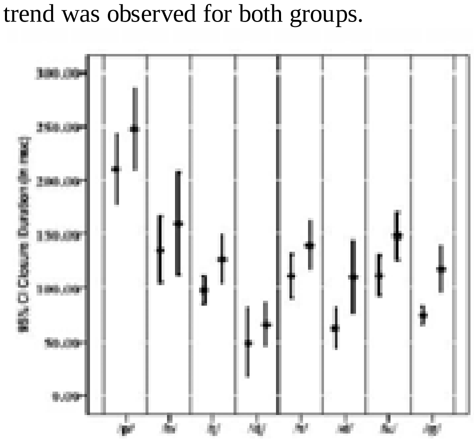
Graphs 1 shows error bar graph for vowel duration for preceded low mid open vowel /a: / for normal and children with unoperated cleft palate. Mann-Whitney Test results revealed significant difference in vowel duration for all the target consonants except /g/ when it is compared across the group. Findings of the of present study related to vowel duration is in support of Casal et al (2002) and Chen, Yang, Wu, Zang, and Wang (2005) they found that, vowel /a/ had longer duration when compared to that of control group. They also reported that, this is due to wider opening of the mouth which leads longer the duration. In children with cleft palate often used abnormal mouth opening and lengthen duration in order to be understood by the listener.

Closure duration (CD): Closure duration was analyzed from the spectrogram. Table 3 shows the mean, SD and mod Z value for Closure duration for both normal and unoperated CP. It is evident that closure duration for unoperated children group was found to be longer when compared to that of the control group. Closure duration was longer for voiceless consonants when compared that of voiced consonants the same trend was observed in both the groups

Table 3: *Mean, SD and Mod Z value for Closure Duration (CD) across the group*

CD	Normal		UnCLP		Mod Z Value	P value
	Mean	SD	Mean	SD		
/p/	210.7	44.7	247.7	52.3	1.361	>0.05
/b/	135.3	42.2	159.4	66.2	0.151	>0.05
/ʈ/	97.9	19	126.9	30.4	2.117	<0.05
/ɖ/	48.9	43.3	66.2	27.3	1.512	>0.05
/t/	111.3	28.3	139.9	30.1	1.816	<0.05
/d/	62.6	24.3	110	44.4	2.858	<0.001
/k/	111.4	25.8	148.2	29.9	2.419	<0.05
/g/	74	10.2	117.6	27.6	3.103	<0.001

From the table it is evident that the closure duration decreased from front /p/ (Normal 210.7msec, UnCP 247.7msec) to back /g/ (Normal 74 msec, UnCLP 117.6msec) same trend was observed for both groups.



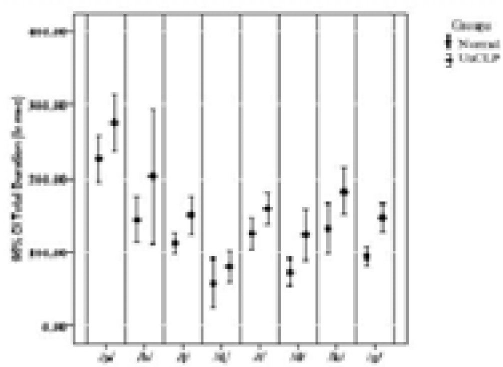
Graph 2: Closure duration for normal and unoperated CP

Graph 2 shows error bar graph for closure duration for normal and unoperated CP. From the graph is evident that closure duration for unoperated children group was found to be longer when compared to that of the control group. Mann-Whitney Test results revealed significant difference in closure duration for /ʈ/, /t/, /d/, /ɖ/, /k/, /g/ when it is compared across group. Findings of the present study related to closure duration are in support of Gaylord and Zajac (2006) & Subramaniyam, Savitha and Biji (2011). The overall longer closure duration in the stop consonants could be attributed to exaggerated laryngeal gestures used to compensate for a decrease in oral pressure in the individuals with CLP. Decreased closure duration from bilabials /p/ to velar/g/ may be attributed to involvement of the tongue to help in compensate production of stop consonants. It is reported that children with cleft palate have less mobility of the tongue that occupies a low posterior portion. Gaylord and Zajac (2006) reported that children with cleft palate have attempt to shorten stop segments to reduce the temporal window for listeners to perceive nasal air emission .They have observed spectral noise in spectrographic analysis of the stop which is most likely resulting from nasal air escape. Hence, children with velopharyngeal dysfunction may be likely to reduce duration of the stop gap in order to avoid prolonged nasal air emission which can be a perceptually distracting speech quality.

Total duration (TD): Total duration was analyzed from the spectrogram. Table 4 shows the mean, SD and Mod Z value for total duration for both normal and unoperated CP. It is evident that total duration for all the target consonants were found to be longer when comparered to that of the control group. Total duration was longer for voiceless consonants when compared that of voiced consonants the same trend was observed in both the groups. Form the table it is evident that the closure duration decreased from front /p/ (Normal 226.4msec, UnCP 275.7msec) to back /g/ (Normal 94 msec, UnCLP 147.6msec) same trend was observed for both control and experimental groups.

Table 4: *Mean, SD and Mod Z value for Total Duration (TD) across the group*

TD	Normal		UnCLP		Mod Z Value	P value
	Mean	SD	Mean	SD		
/p/	226.4	44.7	275.7	54.2	1.588	>0.05
/b/	144.6	43.6	202.7	127.9	0.756	>0.05
/ṭ/	112.2	19.8	151.1	36	2.570	<0.05
/ḍ/	58.8	46.3	81.5	29.4	1.814	>0.05
/t/	126.1	29.8	159.9	31	2.343	<0.05
/d/	73.5	25	124.3	45	2.531	<0.05
/k/	132.4	47.5	182.5	42.7	2.193	<0.05
/g/	94.6	17.5	147	24.7	3.512	<0.001



Graph 3: *Total duration for normal and unoperated CP*

Graph 3 shows error bar graph for total duration of the target consonats for both normal and children with UnCP. Mann-Whitney Test results revealed significant difference in Total duration for /ṭ/, /t/, /d/, /k/, /g/ when it is compared across group. Findings of the present study related to total duration is in support of Chen, Yang, Wu, Zang, and Wang (2005) study. They have reported a significant difference in the duration of the consonants individual with CLP. The reason for increase in the total duration may be due to the prolongation of the phonemes in the target word especially in children with cleft palate. Cleft palate speaker use prolongation as a compensation strategy to achieve a normal production this leads to longer duration.

Conclusions

The results of the present study showed that, children with unoperated cleft group showed longer vowel duration, closure duration and total duration when compared that of the control group. These temporal parameters were compared with across the group results revealed a significant different. The present study also gives information about some temporal characteristics about stop consonants production of children with unoperated cleft palate in Kannada language.

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References

Boersma & Weenink. (2010) Praat software version 5.1.27. http://ww.fon.hum.uva.nl/praat.

Casal,C.,Dominguez,C., Fernandez,A., Sarget,R., Eugenio,M., Joan,S.,& Cosme,G (2002). Spectrographic measures of the speech of young children with cleft lip and cleft palate. *Folia Phoniatrica et Logopaedica*, 54,247-257.

Chen, Yang, Wu, Zang, and Wang (2005). The acoustic features of the consonants of the patients with post palatoplasty velopharyngeal incompetence. *China journal of oral and maxillofacial surgery*, 4, 279-284.

Forner (1983).Speech segment duration produced by five and six year old speakers with and without cleft palate. *Cleft palate Journal*, 20,185-198.

Gaylord and Zajac (2006). Temporal characteristics of alveolar stop consonants produced by children with varying levels of velopharyngeal dysfunction. Master's thesis submitted to the University of North Carolina.

Raju, S, S. (2000). Study of children born with cleft lip and palates in India. An Unpublished study by Tata Institute of Social Sciences, Mumbai. Cited in Sunitha, R., Monica, J., Manju, S, J., & Nagarajan, R (2004). Providing intervention services for communication deficits associated with cleft lip and/or palate –A retrospective analysis. *Asia pacific Disability Rehabilitation Journal*, 15, 2, 78-85.

Singhi, P., Kumar, M., Malhi, P., & Kumar, R. (2007). Utility of the "WHO Ten Questions Screen for Disability "detection in a rural community—the North Indian Experience. *Journal of Tropical Pediatrics*. 53, 6, 383-387.

Subramaniyam, Savitha & Biji (2011). Acoustic analysis of glottal stop in children with cleft lip and palate. *Proceedings of the 10th Annual meeting of Indian Society of cleft lip, palate and craniofacial anomalies*, 86-87.

Vasanthi (2001). Some acoustic aspects in the speech of cleft palate speakers. Unpublished Masters Dissertation, Submitted to the University of Mysore.

ADAPTATION OF MISSISSIPPI APHASIA SCREENING TEST TO TELUGU LANGUAGE

[1]Nagendar K. & [2]Swathi Ravindra

Abstract

Aphasia is an acquired language disorder seen in adults which results from stroke or cerebral injury. Most of these patients with severe language disabilities are difficult to assess and may not also be cooperative for lengthy aphasia test batteries like WAB, BDAE etc., hence the need to develop a screening test. Mississippi Aphasia Screening Test is one such instrument developed by Nakase-Thompson (2005) for this purpose. Very few aphasia screening tests have been developed in the Indian context and none for Telugu. Therefore the present study aimed at adaptation of Mississippi Aphasia Screening Test to Telugu (MAST –T). MAST- T consists of Expressive and Receptive indices, under 9 subtests, with a total of 46 items. It was administered on three groups – Neuro-typical group (NT, n=50), Left Hemisphere Damage group (LHD; n=25) and Right Hemisphere Damage group (RHD; n=05). The test displayed good construct, very good criterion validity (r =0.84), and high inter-rater reliability (r=0.993). Overall, LHD group showed more impairment than RHD group on both the subtests. Also the results showed that neuro-typical performed better than both the groups on all the 46 items, except object recognition task which had almost same score for all three groups. Thus, MAST-T is a reliable and valid screening tool for the detection of aphasia for Telugu speaking persons with aphasia.

Key words: *Assessment, Screening, Aphasia, Telugu*

The communication impairment in Post stroke aphasia is manifested as listening, speaking, reading, and writing-although not necessarily to the same degree in each. It is a major source of disability, leading to impaired language, reduced social activity, depression, and a lower probability of resuming work. Assessment of communication skills and language functions, to provide information to guide medical and rehabilitation interventions, to detect improvement or decline in clinical status, to provide feedback to the family, (Wright, 2000), and so on are important. The standard aphasia assessments (like MTDDA, PICA, BDAE, and WAB) are able to evaluate the presence, type and severity of a language disability (Chapey, 1994), while screening tests like The Aphasia Screening Test (AST, Whurr, 1974), Mississippi Aphasia Screening Test (MAST, Nakase-Thompson, 2005), Frenchay Aphasia Screening Test (FAST, Enderby, et al., 1987) etc., are done to detect the presence or absence of aphasia. Both come with their advantages and disadvantages. Adaptation of aphasia tests into Indian languages with appropriate social, cultural and linguistic modifications have also been done. Some of the recently developed tests are: Malayalam version of Boston Diagnostic Aphasia Examination-3 (Sona, 2004)**;** Telugu version of Western Aphasia Battery (Sripallavi, 2010) etc.

The domains of assessment vary based on the purpose, for e.g. MTDDA or WAB can be used for differential diagnosis, functional communication can be obtained by PICA etc. The purpose of a screening test would be to identify the presence or absence of aphasia (Chapey, 1994). To assess the components of production and expression of language: Naming, Automatic Speech, Repetition, Yes/No Responses, Object Recognition, Following Verbal Instructions, Reading Instructions, Writing and Verbal Fluency are commonly used.

According to Moore, et al (1996) naming is located in left temporal extrasylvian regions, left anterior insula and right cerebellum. Study conducted by Bookheimer, et al. (2000) showed that automatic speech is located in posterior superior temporal lobe (Wernicke's area) and in Broca's area, while repetition is located in the anterior insula, a localized region in the lateral premotor cortex, and the posterior palladium (Wise, et al. 1999**)**.

Studies found that left inferior frontal gyrus was involved both for verbal fluency (Gaillard, et al., 2003) and lexical decision making (Wright, et al., 2010), while object recognition was located in lateral and ventral occipito-temporal areas (Grill, 2003). Writing was located in the left

[1]Clinical Supervisor, Dept. of Speech and Audiology, Sweekaar Academy of Rehabilitation Sciences, Secunderabad, Email: nagender.maslp@gmail.com & [2]Principal, Helen Keller Institute of Speech and Hearing, Secunderabad, Email: bythaswathi@yahoo.co.uk

posterior inferior temporal cortex (Nakamura, et al., 2000). Roux, et al. (2004) found that reading was located in the lower part of the pre- and postcentral gyri, angular and the posterior part of the superior temporal gyri, the inferior and middle frontal gyri and the posterior part of middle temporal gyrus of the dominant hemisphere. Thus, it can be seen that the whole brain is involved in the processing of different components of language and these need to be assessed to obtain an overall view about the breakdown.

Assessment for patients with severe language impairments, by using formal diagnostic batteries could have various disadvantages; however, a short screening test might be a better option. It will also be useful to predict prognosis and measure patients' progress. There are now considerable number of tests for aphasia available in English and other Indian languages; however, there are no aphasia screening tests available for Telugu, one of the four major Dravidian languages widely spoken in Andhra Pradesh of southern part of India.

Therefore the present study attempts to design an Aphasia Screening Test in Telugu. Such a screening test would help in bedside evaluation in hospital setup in identifying the persons with aphasia, describing the aphasia for the purpose of early diagnosis, therapy and prognosis.

The aim of this study was to adapt and develop Telugu version of the Mississippi Aphasia Screening Test. The specific objectives were: 1) to translate MAST to Telugu, 2) to obtain the criterion and construct validity, 3) to obtain inter-rater reliability and 4) to administer it on a group of Telugu speaking persons with aphasia.

Method

Study was done in two phases. In the first phase, the translation of English version into Telugu was done and in the second phase the test (MAST-T) was administered. The adaptation of the MAST-T was undertaken after obtaining approval from the author, Nakase-Thompson.

Participants

A total of 80 Telugu speaking participants took part in the current study. They were distributed into three groups: Neuro-typical (NT), persons with aphasia with left hemisphere damage (LHD) and persons with aphasia with right hemisphere damage (RHD). The purpose of administering on the neuro-typical group was to standardize test while difference in performance across subtests, if any, was to be obtained by administering on different aphasic groups.

The neuro-typical group consisted of 50 adults(divided into 5 groups, with 10yrs interval, having 10 persons in each group) in the age range of 18-68 years (mean: 43.9 yrs, SD:3.2), while the LHD group consisted of 25 participants (mean:50.6 yrs, SD:11.4) and the RHD consisted of 5 participants (mean:54 yrs, SD:12.4). The inclusive criteria for both the aphasic groups were: stoke due to CVA either in LH or RH, right handed, preferably not attending speech therapy and having no other associated problem.

Procedure

The test used in the current study was developed by Nakase-Thompson, et al. (2005). It consists of nine subtests categorized under two main indexes - Expressive language index and Receptive language index. The Expressive Language Index included 5 subtests: a) Naming, b) Automatic speech, c) Repetition, d) Verbal fluency and e) Writing. The Receptive Language Index included 4 subtests: a) Yes/ No Responses, b) Object recognition, c) Following instructions and d) Reading instructions. The former has 21 test items, while the latter has 25; a score of 50 for each could be obtained, both these indices added up to a total of 100.

All the of nine subtests categorized under two main indices -Expressive language index and Receptive language index of the English version were translated to Telugu and adapted keeping in view the linguistic, social and cultural factors in the first phase. The translated version was reviewed by a Linguist to obtain content validity and suggested modifications were incorporated.

In the second phase, data collection from 30 persons with aphasia was done at various hospitals and for a few at home, while for forming the neuro-typical group 30 participants (age, education and gender matched) were taken from the 50 neuro-typical group, on whom the standardization of the test was done . All responses of the participants were audio-recorded. Scoring and appropriate statistical analyses of samples were done. A score of '1' was given for correct response and '0' for incorrect or any type of errors. All subtests put together had 46 test items and a total score of 100 could be obtained.

Data was also collated from the patient files, interviews and from caretakers to obtain the medical and demographic information for the aphasic group which included age, gender, educational level, handedness, neuroimaging findings and duration of time since stroke, while for the neuro-typical the demographic data was collected through interviews.

Results and Discussion

In the present study, the aim was to adapt and develop Telugu version of Mississippi Aphasia Screening Test (MAST-T) which was administered on 50 neuro-typical persons and 30 persons with aphasia.

Adaptation of the test

The translated Telugu version of MAST had the same number of subtests, same number of items and same scoring method as English version. The test took about 10 to 15 minutes to administer. The performance of neuro-typical group is depicted in the following table.

Table-I: *Scores on all subtests of MAST-T version for the neuro-typical group*

Subtest	Max. Score	Age groups									
		18-28yrs (N=10)		29-38yrs (N=10)		39-48yrs (N=10)		49-58yrs (N=10)		59-68yrs (N=10)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
EI	50	49	1.05	46.7	2.71	46.2	2.9	43.8	4.08	44.6	4.27
RI	50	50	0	49.6	0.84	49.4	0.97	49.2	1.4	48.2	1.48
TS	100	99	1.05	96.3	2.63	95.6	3.03	93	4.94	92.8	4.64

Note: EI: Expressive Index, RI: Receptive Index and TS: Total Score.

From the above table it can be noted that (a) as the age increased, there was a decrease in overall performance on MAST-T, (b) the expressive index (EI) showed gradual decline in the performance, however (c) the receptive index (RI) was almost constant. This decline in the scores may be attributed to probable decrease in the cognitive capacities as age increases. These norms will help the clinician to judge whether a persons with aphasia deviates from the expected (typical) performance levels or not.

Validity and reliability measures of MAST-T

Construct validity was obtained by a Linguist and while the criterion validity were obtained by administering both English and Telugu version of MAST on 10 bilingual speakers of Telugu and English. High degree of correlation was obtained using Pearson correlation (0.84) between the two versions. The inter-rater reliability was good and test-retest reliability was high (r=0.993). This reveals that the developed test consistently measured the attributes that they were intended to measure.

Demographic variables and MAST-T findings

A summary of findings on the demographic variables studied in the current study are presented in Table-II.

Table-II: *Findings on Demographic variables*

Sl. No	Variable	NT gp (n=30)	LHD gp (n=25)	RHD gp (n=5)	Sig(*p*)
1	Age* M (SD)	51.06 (11.39)	50.5 (11.41)	54 (12.42)	Not Sig
2	Education* M (SD)	14.43 (2.6)	14.48 (3.2)	9 (4.94)	<0.001 (LHD & NT) <0.001 (RHD & LHD)
3	Duration** M (SD)	–	39.24 (13.28)	37.6 (18.2)	Not Sig
4	Gender Male Female	 53.30% 46.60%	 84% 16%	 40% 60%	 <0.05 (LHD)
5	Handedness Right Left	 100% 0%	 100% 0%	 100% 0%	 Not Sig

* in years; **in months post onset

Significant difference was not found in terms of age for the three groups. However, in the English version Nakase-Thompson (2005) found significant difference between the aphasic and control group in terms of age i.e. the control group were much younger. In the current study, a possible reason for not finding a significant difference could be due to matching of the participants in terms of age hence no difference.

There was no significant difference in terms of educational level between the NT group and LHD group, but there was a significant difference between the NT & RHD group (p<0.001), and LHD & RHD group (p<0.001). This suggested that the RHD group participants had less years of education than the other two groups. There was no significant difference in terms of duration (*p*= 0.814) between the two patient groups. As all right handed participants were selected, there was no difference between the three groups, for handedness variable. One-way ANOVA suggested that there was a significant difference in terms of gender in LHD group (p<0.05) i.e. more number of male participants were observed but no such differences were found in NT and RHD groups. Expressive Index and Total Score were found to be significantly associated with age, education and handedness, while for the Receptive Index; gender was significantly associated, in the English version of MAST.

Performance on MAST-T

Performances of the three groups on MAST-T are summarized in Table-III. Between groups comparisons were done using ANOVA and t-test and the results of post-hoc pair wise comparisons revealed that, overall mean scores of both LHD group and RHD group were qualitatively reduced when compared to the Neuro-typical group. Thus, it can be seen that MAST-T could differentiate the aphasic group from the neuro-typical group.

The LHD group's performance was markedly poorer than NT & RHD group on all the 12 subtests of MAST-T version. Performance of RHD group was similar to neuro-typical group for all the nine tasks except verbal fluency and reading instructions, in which lower performances were seen. Ceiling effect was seen in the neuro-typical group for only two of the nine tasks i.e. naming and object recognition task and lowest score was obtained for verbal fluency.

Performance on expressive index indicated that RHD and NT groups had similar performance while the LHD group was poorer when compared to both the groups. Performance on receptive index indicated that both the LHD and RHD groups had poorer score when compared to NT group.

Performance on the English version, showed: (i) LHD group performed significantly poorer than non patient group on all 12 MAST subtests, (ii) LHD group performed significantly poorer than RHD on 10 of the 12 subtests and (iii) RHD group performed significantly poorer than Non Patient group on 7 of the 12 subtests (Nakase-Thompson, 2005).

Table-III: *Performances on MAST-T by the three groups*

Group/ Task	LHD		RHD		Neuro-typical		Sig*
	Mean	SD	Mean	SD	Mean	SD	
Naming	4.32	3.5	8.8	1.1	10	0	0.001(a,c)
Automatic Speech	5.04	3.3	8.4	0.9	9.33	0.9	0.001(a) and 0.005(c)
Repetition	6.32	3.7	8.4	0.9	9.4	1.2	0.001(a)
Writing	0.56	1.5	8.4	1.7	8.6	1.4	0.001(a,c)
Verbal Fluency	1.6	2.4	5	0	7.67	2.5	0.001(a) and 0.005(c)
Yes/ No Responses	13.84	4.8	17.2	1.1	19.47	0.9	0.001(a) and 0.005(c)
Object Recognition	9.76	0.9	9.6	0.9	10	0	-
Following Instructions	5.92	2.6	8.8	1.1	9.8	0.6	0.001(a) and 0.005(c)
Reading Instructions	3.12	3.2	7.6	1.7	9.73	0.7	0.001(a,c)

* *a=LHD group poorer than neuro-typical group, b= LHD group poorer than RHD group and c= RHD group poorer than neuro-typical group*

Comparison of performance between the LHD group and NT in MAST-T revealed marked poor performance on writing and verbal fluency, poor performance on naming, automatic speech, following instructions & reading instructions and comparable performance for repetition and yes-no questions. Comparison of performance between the RHD group and NT revealed comparable performances on 6 of 12 subtests and slightly poor performance for 3 i.e. on yes-no questions, following instructions and reading instructions.

Because writing to dictation requires motor performance and left hemisphere was dominant for this task in a right handed person, the LHD group performed poorer on this task. Poor performance for verbal fluency is supported by Gaillard (2003), who found that left inferior frontal gyrus and left middle frontal gyrus of the brain were responsible for the verbal fluency; hence it was a left hemisphere dominant task.

Poor performance on naming subtest can also be noted as naming is one of the language dependent tasks and the left hemisphere was dominant for this function, hence, the LHD group performed poorer than RHD and NT groups. This finding is supported by Willem (1998) and Moore (1996), who found that naming was located in the left posterior temporal lobe, left posterior basal temporal lobe, left temporal extrasylvian regions and left anterior insula. Performance on automatic speech subtest indicated that RHD and NT groups had similar performance while the LHD group was poorer when compared to both the groups. Bookheimer (2000), reported that left posterior superior temporal lobe (Wernicke's area) and Broca's area of the brain were responsible for the automatic speech task, hence the poor performance.

Performance on object recognition subtest indicated that the three groups i.e., NT, RHD and LHD groups had similar performances, possibly indicating that both the hemispheres are involved in this task. Performance on writing subtest indicated that RHD and NT groups had similar performance while the LHD group was poorer when compared to both the groups. Object recognition and following written instructions subtests depend on visual-perceptual abilities. Since these types of tasks are difficult for patients with left neglect, hence the low score in performance. These findings are supported by Grill (2003), and Nakamura (2000). Thus, as noted by Nakase-Thompson (2005) visual analysis task may partially explain sensitivity to right hemisphere injury.

Following verbal instructions subtest comprises following instructions that increase in length. This task was poorly performed by LHD group. As this task requires higher language functions like language comprehension, attention, left/right discrimination and body schema, which are associated with left hemisphere. Performance on repetition subtest indicated that both the LHD and RHD groups had poorer performance when compared to NT group. According to Hagenbeek (2007), both anterior and posterior cingulate cortices and the left middle frontal gyrus of the brain are responsible for word repetition. While Wise (1999**),** noted that repetition was located in the anterior insula.

To summarize, comparable scores were obtained for all the 9 subtests of MAST English and Telugu versions except for the repetition task, in which the difference in performance between the LHD and RHD was greater in the English version. Overall in both the versions the LHD performed poorer than RHD in naming, automatic speech, Following Instructions and Reading instructions. The LHD performed markedly lower than RHD on writing and verbal fluency task. Equal performances were seen for repetition, yes-no questions and object recognition.

Conclusions

The findings of this study indicate evidence of high validity and reliability of MAST Telugu version. The scores could differentiate the aphasic group from the neuro-typical group and also the LHD from the RHD group. Overall it can be concluded that as the left hemisphere is dominant for the language and cognitive functions, hence in this test the LHD group got poor scores than RHD group. The test also showed good construct and criterion validity along with good test-retest and inter-ratter reliability. However, correlation with other screening tests of aphasia and testing on larger population needs to be done. Thus, MAST-T provides an objective screening tool for assessing aphasia in Telugu language**.** It can also be used to measure the prognosis and plan therapy. It can also be useful in counseling the family members regarding the patient's language abilities and disabilities.

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References

Bookheimer, S. Y., Zeffiro, T.A., Blaxton, T.A., Gaillard, P.W., Theodore, W.H. (2000). Activation of language cortex with automatic speech tasks. *Neurology*, 55(8)*:*1151-1157.

Chapey, R. (1986). *Language Intervention Strategies in Adult Aphasia* (2nd Ed.). Baltimore, MD: Williams and Wilkins.

Chapey, R. (1994). *Language Intervention Strategies in Adult Aphasia* (3rd Ed.). Baltimore, MD: Williams and Wilkins.

Enderby, P. M., Wood, V. A., Wade, D. T., Langton Hewer, R. (1987). The Frenchay Aphasia Screening Test: A short, simple test for aphasia appropriate for nonspecialists. *International Journal of Rehabilitation Medicine*, 8:166-170.

Gaillard, W.D., Sachs, B.C., Whitnah, J.R., Ahmad, Z., Balsamo, L.M., Petrella, J.R., Grandin, C.B. (2003). Developmental Aspects of Language Processing: fMRI of Verbal Fluency in Children and Adults. *Human Brain Mapping,* 18 (3):176-185

Grill, K. (2003). The Neural Basis of Object Perception. *Current Opinion in Neurobiology,* 13 (2):1-8.

Hagenbeek, R.E., Rombouts, S.A., Veltman, D.J., Van Strien, J.W., Witter, M.P., Scheltens, P., Barkhof, F. (2007). Nonlinear Changes in Brain Activity during Continuous Word Repetition: An Event-Related Multiparametric Functional MR Imaging Study. *American Journal of Neuroradiology*, 28 (9):1715-1721.

Moore, C.J. (1999). Three distinct ventral occipitotemporal regions for reading and object naming**.** *Neuroimage***,** 10(2):181-92.

Nakamura, K., Honda. M., Okada, T., Hanakawa, T., Toma, K., Fukuyama, H., Shibasaki, H. (2000). Participation of the Left Posterior Inferior Temporal Cortex in Writing and Mental Recall of Kanji Orthography. *Brain,* 123 (5): 954-967.

Nakase-Thompson, R., Manning, E., Sherer, M., Yablon, S.A., Gontkovsky, S.L., Vickery, C. (2005). Brief assessment of severe language impairments: Initial validation of the Mississippi aphasia screening test. *Brain Injury,* 19(9): 685–691.

Roux, F. E. (2004). Intra-Operative Mapping of Cortical Areas Involved In Reading in Mono and Bilingual Patients. *Brain*, 127 (8):1796-1810.

Sona, A.N. (2004), *Development of Indian and Malayalam Version of Boston Diagnostic Aphasia Examination-3***.** An unpublished Masters Dissertation, University of Mysore, Mysore.

Sri Pallavi, M. (2010). *Development of Western Aphasia Battery in Telugu***.** An unpublished Masters dissertation, University of Mysore, Mysore.

Whurr, R. (1974). Aphasia Screening Test. http://www.speechmark.net/aphasia-screening-test-ast- 3rd-edition

Wise, R.J., Greene, J., Büchel, C., Scott, S.K. (1999). Brain regions involved in articulation. *Lancet*. 353(9158):1057-61.

Wright, P., Randall, B., Marslen-Wilson, W.D., Tyler, L.K. (2010). Dissociating Linguistic and Task-related Activity in the Left Inferior Frontal Gyrus. *Journal of Cognitive Neuroscience.* 23 (2):404-413.

EFFECT OF BILINGUALISM ON CREATIVITY–AN EXPLORATORY STUDY

[1]Amrutha Madhav, [2]Anjali Anand, [3]Swapna N. & [4]Sangeetha G. S.

Abstract

Bilingualism is the process of knowing or using two languages with equal or nearly equal fluency. Research evidences have suggested that cognition specifically creativity is affected by the process of learning one or more languages. In this context, the current study was aimed to investigate the creative abilities of bilingual and monolingual adolescents. A total of 24 participants (12 monolinguals and 12 bilinguals) were considered for the study. Four verbal subtests from the Passi test of creativity and two nonverbal subtests of creativity developed by Veena and Bhavani (2002) were administered on the selected participants. The responses obtained from both the groups were scored as per the instructions provided in the manual of the tests. The scores were averaged across participants of both the groups and were subjected to statistical analysis. The results of the present study revealed that bilinguals outperformed the monolinguals in all the subtests of creativity which indicated that the bilinguals were more creative than monolinguals. There was a definite advantage of bilingualism on the creative abilities of the individuals considered in the study. The results of this study helps us to refine our understanding of the thought process in bilingual individuals and may contribute towards reframing the notion in people's mind that bilingualism hampers the development of the child. Further research is warranted considering a large sample of subjects, in different languages, in different age groups and in different types of bilinguals to discover the exact relationship between bilingualism and creativity.

Key words: *Creativity, bilinguals, monolinguals*

Bilingualism has been an area of great interest in the field of research for the past few decades and has been receiving increasing attention. Bilinguals are individuals who are fluent in two languages; or individuals who actively use, or attempt to use more than one language, even if they have not achieved fluency in their second language (Kroll & de Groot, 1997). The bilinguals are different from monolinguals in many ways. The differences are evident in the way they acquire language, age of acquisition, proficiency in the language etc. Bilinguals are constantly involved in the process of comparing and contrasting the two languages, for example; comparing nonsense of meaning, attending to different grammatical forms. They may be persistently vigilant over their languages, inspecting them and, resolving interference between the languages. Bilinguals are also different from monolinguals in terms of language storage in their brain. Vaid and Hull (2002) found left hemisphere dominance for language processing in monolinguals whereas bilateral involvement was pronounced in early fluent bilinguals. Thus, bilinguals appeared to be less left lateralized than monolinguals which suggested that learning a second language increases the density of grey matter (Mechelli, Crinion, Noppeney, O'Doherty, Asburner, Frackowiak, & Price, 2004).

It is a common view that one's personality grows with the extra languages- particularly among those who are already bilingual.

Apart from the influence on personality, the knowledge of extra languages also influences other domains such as linguistic and metalinguistic skills, cognition, and academics (Ianco-Worrall, 1972; Cummins & Gulutsan, 1974; Ben-Zeev, 1977a, 1977b; Cummins, 1978; Bialystok, 1991, 1999, 2001). These domains are closely related and interlinked to each other (Vygotsky, 1986). There is a growing body of literature on how bilingualism affects an individual's linguistic, metalinguistic, cognitive and academic performance.

In the early 1900s, there were claims that teaching a child a second language could suppress intellectual function and cause emotional problems (Hakuta, 1986). The period where research accented detrimental effects on bilingualism lasted from approximately the 1920's to the 1960's. While the dominant result was that bilinguals were inferior to monolinguals particularly on verbal Intelligence Quotient (IQ), these early studies share various limitations and methodological flaws and hence, the conclusions cannot be accepted (Grosjean, 1998). Modern research suggests that the bilinguals have no cognitive disadvantages compared to the

[1]Speech Language Pathologist and Audiologist, Ephphatha Speech and Hearing Centre, Kerala, Email: amruthamadhav5@gmail.com, [2]Student, National Institute of Speech and Hearing, (NISH) Kerala, Email: anjali.maslp @gmail.com, [3]Lecturer in Speech Pathology, All India Institute of Speech and Hearing, (AIISH) Mysore-06, Email: nsn112002@yahoo.com, & [4]Research Officer, AIISH, Mysore-06, Email: sangeethags.slp @gmail.com

monolinguals. Further, there are ample numbers of studies which were carried out subsequently that supported the view that speaking two languages does not tax either the cognitive or the linguistic system; rather bilingualism confers advantages upon children with respect to various cognitive and linguistic abilities. Bilingualism influences the cognitive processes including the conscious functioning and the unconscious automatic cognitive processing such as creativity that requires no attentional control. Creativity is usually considered to be a mental process which involves the generation of new ideas or new connections between existing ideas. Creativity can be manifested in the production of creative outcomes that are both original and useful (Simonton, 2008; Saul & Leikin, 2010). An alternative, more common conception of creativity suggests that it is simply the act of making something new and different from what others are making (Leikin, 2009).

In psychometric tradition, creative thinking is perceived as an ability to initiate multiple cycles of divergent and convergent thinking (Guilford, 1967), which creates an active, attention-demanding process that allows generation of new, alternative solutions (Mumford, Mobley, Uhlman, Reiter-Palmon, & Doares, 1991). Guilford (1967) introduced a distinction between convergent and divergent thinking. The fundamental difference between these two processes is that convergent thinking is a conscious, attention demanding process, whereas divergent thinking occurs in the unconscious mind, where attention is defocused (Mendelsohn, 1976; Kasof, 1997) and thought is associative (Koestler, 1964; Mednick & Mednick, 1967; Ward, Smith, & Vaid, 1997). Divergent thinking involves a broad search for information and the generation of numerous novel alternative answers or solutions to a problem (Guilford, 1967). Divergent thinking is sometimes used as a synonym for creativity in psychology literature. Other researchers have occasionally used the term flexible thinking (Tranter & Koutstaal, 2008).

According to Guilford (1967) divergent thinking is associated with four main characteristics: fluency (the ability to rapidly produce a large number of ideas or solutions to a problem); flexibility (the capacity to consider a variety of approaches to a problem simultaneously); elaboration (the ability to think through the details of an idea and carry it out); and originality (the tendency to produce ideas different from those of most other people).

Several researchers investigated the relationship between bilingualism and creative thought. The literature is abundant, albeit controversial, with evidence of negative, positive, or neutral influence of bilingualism on the development of different specific cognitive abilities and processes, including different forms of creativity (Ricciardelli, 1992a; Bialystok, 2005; Simonton, 2008). According to many researchers, bilingualism can indirectly stimulate the creative process that is dependent on cognitive capacities. The advantages of bilingualism have been reported across a variety of domains, such as creativity and flexibility, (Torrance, 1966, 1974; Landry, 1973; Bruck, Lambert, & Tucker, 1976; Kessler & Quinn, 1987; Ricciardelli, 1992a; 1992b; Simonton, 2008) and perceptual disembedding (Duncan & De Avila, 1979). A review of the available literature shows a tendency for bilinguals to perform better than their monolingual counterparts on various test of creative thinking.

Balkan (1970) reported of some advantages in thinking, ranging from creative thinking to measures of cognitive flexibility, creativity or divergent thought to faster progress in early cognitive development and greater sensitivity in communication in bilinguals. Peal and Lambert (1962) compared 10 year old French-Canadian balanced bilinguals with their English or French counterparts on measures of nonverbal and verbal intelligence. The results revealed that on both the intelligence measures, the bilingual group performed better than the monolingual group. The bilinguals were also rated better than the monolinguals in general school achievement. They concluded that bilingualism provides greater mental flexibility in terms of thinking more abstractly and more independently of words. The bilingualism also facilitated superiority in concept formation and development of IQ.

Cummins and Gulutsan (1974) replicated the study of Peal and Lambert (1962) in Western Canada in which balanced bilingual group matched with a monolingual control group on socioeconomic status, gender and age performed better than the controls on verbal and nonverbal ability measures and on verbal originality measure of divergent thinking. Landry (1974) assessed creativity in bilinguals and reported that when a second language was learned at a critical age, performance on measures of figural and verbal fluency, flexibility and originality was significantly better compared to monolinguals.

Ben-Zeev (1977a) studied Hebrew-English and Spanish-English bilingual children and concluded that bilinguals process the semantic information more deeply than monolinguals.

They thus show greater cognitive flexibility and greater ability to use more complex analytical strategies in their approach to language operations. Bilingualism created advantages in terms of cognitive abilities. It extended the individuals' capabilities and promotes mental processing (problem solving, thinking, flexibility and creativity) (Kormi-Nouri, Moniri, & Nilsson, 2003). Bilinguals can extend the range of meanings, associations and images, and think more fluently, flexibly, elaborately and creatively.

Kharkhurin (2008) evaluated the performance of Russian-English bilinguals and English monolinguals on divergent thinking tasks. The results revealed that the bilinguals who acquired their second language earlier, those with high proficiency in both the languages and with longer exposure to the new cultural settings tended to outperform their counterparts who acquired second language later in life, and with less proficiency on the measures of fluency and flexibility in divergent thinking. He proposed that age of second language acquisition, linguistic proficiency, and length of exposure to a new cultural environment might influence the performance of bilinguals.

Kharkhurin (2009) compared the performances of Farsi-English bilinguals living in the UAE and Farsi monolinguals living in Iran on the Culture Fair Intelligence Test battery and two creativity tests. The findings revealed that bilingualism facilitated the innovative capacity, i.e., the ability to extract novel and unique ideas. However it was found that bilingualism did not facilitate the ability to generate and process a large number of unrelated ideas. Bilingualism was related to higher originality scores for the divergent thinking test and the tendency to break away from standard category properties in the structured imagination task.

To account for bilingual advantages on creative performance, Kharkhurin (2009) proposed a Language Mediated Concept Activation (LMCA) model. He argued that LMCA may activate unrelated concepts in bilingual memory which could facilitate the generative capacity in bilinguals. The basic conception of the model is that the specific architecture of bilingual memory may facilitate the greater spreading activation between concepts. Variations in the conceptual representation of translation equivalence may result in the simultaneous activation of additional concepts. This may produce a large pattern of activation over unrelated concepts from different categories. Thus elaborative LMCA may allow bilinguals to process large unrelated concepts from different categories simultaneously, which in turn results in their superior generative capacity. More recent findings showed that the superior innovative capacity of the bilinguals may be determined by various factors in their socio-cultural environment.

Other studies have found the bilingual advantage only on certain aspects of creativity, while some others have found no difference between bilinguals and monolinguals on creativity. Okoh (1980) administered a battery of tests of verbal and nonverbal creativity, verbal intelligence and language proficiency on bilingual vs. monolingual children. It was found that bilingual children scored significantly higher in the verbal creativity tests than their monolingual counterparts, however there was no significant difference between the two groups in the nonverbal creativity tests. Kharkhurin (2010a) found significant differences between nonverbal and verbal creativity in the bilingual context. Positive influence of bilingualism on nonverbal creative behavior was shown; while in verbal creativity measures monolinguals were found to be better than bilinguals.

Stephens, Advisor, Esquivel, and Giselle (1997) investigated the effect of bilingualism on creativity by administering the Torrance Test of Creative Thinking (Torrance, 1966) and on social problem-solving skills using the Preschool Interpersonal Problem Solving Scale. The study was carried out on a group of Spanish-English bilinguals and Spanish monolinguals. The results indicated that the bilingual children performed superior to their monolingual counterparts in the area of social problem solving, but not in the area of creativity.

Need for the study

A look into the literature revealed mixed findings with respect to bilingualism and creativity. Although some studies report a positive relationship between the two, others have only found the effect of bilingualism on certain types of creativity (verbal vs. nonverbal), while a few others have found no difference between bilinguals and monolinguals on creative thinking. Most of the studies have incorporated either verbal or nonverbal measures to assess creativity. The correlation between bilingualism and creativity is a mere spurious upshot of underlying factors of experimental openness of the economy; bilingualism is likely to become more rather than less prominent. Therefore it is essential to learn what the consequences of that trend might be including whether the creative activity is likely to grow, stagnate, or decline.

Further, most of these studies have been carried out especially in children in the west. There are reports which state that there are differences in the linguistic and cognitive functions across races and cultures (Sosa, Albanese, & Prince, 2009). The influence of these factors on language and cognition of individuals cannot be undermined. Further, if the knowledge of more than one language has a significant impact on measures of creativity, scientific research in such domains of bilingualism should take place in abundance in countries like India which is known for its rich multilingual nature. But there has been dearth of studies conducted despite such opportunities especially in domains of creativity. Till date there has been no research conducted on the aspect of creativity in bilinguals in the Indian context. Keeping this in view, the present study was planned and carried out. It is hoped that the results of the study would help open up a new horizon for research in the field of bilingualism in India which is a land known for its rich multi-language culture. The aim of the study was to investigate the creative thinking abilities in bilingual and monolingual adolescents.

Method

Participants: Twenty four female participants in the age range of 15-16 years were selected for the study. They were native speakers of Kannada and were divided into two groups. The group I consisted of 12 Kannada speaking monolingual participants and the group II comprised of 12 Kannada-English bilingual participants. Although the monolingual group had some exposure to English, it was very minimal. The participants were selected from various schools in the city of Mysore. All ethical standards were met for subject selection and their participation.

Participant selection criteria: The participants meeting the following criteria were included in the study:

1. No history of language, speech, hearing, neurological, developmental, academic and intellectual disorders, which was ensured using the 'WHO ten question disability screening checklist' (Singhi, Kumar, Malhi, & Kumar, 2007)

2. Sequential bilinguals with Kannada as mother tongue and English as second language as participants for the group II.

3. A score of 1 and 3 in terms of proficiency in English in ISLPR for the participants of the group I and II respectively. The International Second Language Proficiency Rating (ISLPR) scale developed by Ingram (1985) was used to check the language proficiency in the second language English. ISLPR describes language performance at eight points along the continuum from zero to native like proficiency in each of the four macro skills (speaking, listening, reading and writing). The scale is divided into primary (speaking and listening) and secondary skills (reading and writing). It has 8 ratings which includes 0, 0+, 1, 1, 2, 3, 4, 5 as rated from a continuum zero proficiency to native like proficiency.

4. Average academic performance as reported by their respective class teachers.

5. Participants belonging to middle socio-economic status which was ensured using the NIMH socioeconomic status scale developed by Venkatesan (2009). The scale has sections such as occupation and education of the parents, annual family income, property, and percapita income to assess the socioeconomic status of the participants.

6. Participants who don't have an exposure to any training classes for drawing and painting and other arts which have an impact on their creative abilities.

Material: The Passi Test of creativity developed by Passi (1979) was administered on the selected participants. It is a test developed for the purpose of measuring creativity. Four verbal subtests of creativity from the Passi Test of Creativity were administered on the selected participants. The four subtests were as follows: The seeing problems test, the unusual uses test, the consequences test and the test of inquisitiveness. The details of the subtest and the instructions provided to the participants have been mentioned below:

1. The seeing problems test: The test included four items, namely, shoe, pen, chair and postcard. The subjects were instructed to think and write down briefly as many defects and problems as they can point out in connection with these four items. The maximum time limit provided was 8 minutes, two minutes for each item.

2. The unusual uses test: This test included two items namely, cloth and bottle which could be used for numerous purposes. The participants were expected to write as many interesting and unusual uses as possible for each item. The maximum time limit for the test was 8 minutes; 4 minutes allotted for each item.

3. The consequences test: The test included four items/instances viz. if the human beings start flying like birds, if all houses start flying, if all people become mad and if all females become males. The participants were expected to write down as many consequences of the above

mentioned items as possible. The maximum time limit provided was 8 minutes, two minutes allotted for each item.

4. The test of inquisitiveness: The participants were shown a covered object and were expected to imagine and write as many questions as possible that arise in their mind about the object within 6 minutes. They were also told that the questions should be mutually exclusive to one another in content and meaning.

Subsequent to this, two nonverbal subtests of creativity developed by Veena and Bhavani (2002) was administered on the participants. The details of the tests included were as follows:

1. Completion of figure: The participants were expected to make as many figures as possible from a given shape. Repetitions of figures were not allowed. The participants were given a time span of five minutes to perform the task.

2. Draw the person: The participants were expected to draw a person either girl or boy within a time span of eight minutes. They were given the freedom to draw the picture with all accessories as creatively as they can.

The tests permitted freedom of responses both qualitative and quantitative within specified time limit thus ensuring the suitability of the tools for measuring divergent thinking.

Procedure

The participants were made to sit comfortably in a quiet room with no distractions and instructions were given in Kannada for each task. Rapport was built with the participant before the assessment. The subtests were administered one at a time. A time span of one hour was required to administer the test. The allotted time for each task was according to the instructions given in the manual of both the tests. The written responses of the subjects were recorded in answer sheets provided with the tests. The participants were given reinforcement after the completion of the tasks. The subtests were scored as per the scoring procedure provided in the test for each item. The total score for each subtest of the Passi test was 10. For the first four subtests the answers of the participants were compared with the list of possible answers given in the test material and was scored accordingly. For the subtest on completing the figure, each figure was scored. Figures of alphabets and numbers were excluded and not scored. For the subtest on drawing a person, full score was given if the picture drawn was complete in terms of all body parts, dress and accessories.

Consequently the total score for each of the subtest for each participant was tabulated and was compared with the norms provided in the test. The data thus obtained was averaged across all participants and was subjected to appropriate statistical analysis using a commercially available SPSS package (version 16.0). Statistical procedures such as independent samples t- test was used to compare the performance of the two groups on various subtests of creativity. Descriptive statistics was used to obtain mean and standard deviation in the two groups. An independent samples t-test was used to check for the significant difference, if any between the two groups.

Results

The performance of Kannada speaking monolinguals and Kannada English bilinguals was compared across all subtests of creativity. The mean and Standard Deviation (SD) obtained for each of the subtests have been depicted in Table 1. A comparison of the total mean scores of all the subtests revealed that the bilingual group obtained higher mean scores than the monolingual group which indicated that the bilingual group performed better than the monolingual group. The total mean scores obtained were subjected to independent t- test and the results revealed that there was a significant difference between the monolingual group and the bilingual group at 0.01 level. The t- values have been depicted in Table 1. The performance of the two groups as a whole and on all the subtests has been depicted in Figure 1.

Table 1: *Mean, Standard Deviation (SD) and t values of various subtests of creativity for both the groups.*

Groups	Monolinguals		Bilinguals		t values
Subtests of creativity	Mean	SD	Mean	SD	
Subtest 1	10.33	3.68	16.08	4.64	3.36**
Subtest 2	6.67	2.35	21.17	5.52	8.37**
Subtest 3	4.58	2.97	11.50	3.45	5.26**
Subtest 4	4.25	1.71	13.58	7.30	4.30**
Subtest 5	9.42	3.75	14.25	5.33	2.57*
Subtest 6	15.58	5.74	26.33	11.44	2.91**
Grand total	50.91	12.17	102.92	16.85	8.67**

*p<0.05, **p<0.01

When the mean scores were compared across the subtests, it was seen that both the groups obtained the maximum mean score for the subtest 1 among the verbal subtests which is the ‘seeing problems test’ and for the subtest 6 which is ‘draw a person test’ among the nonverbal subtests.

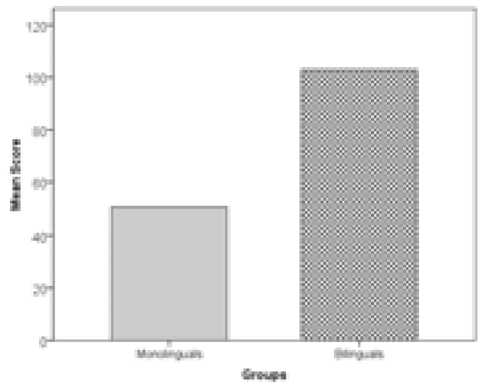

Figure 1: *Performance of the bilinguals and monolinguals on the creativity subtests.*

The mean scores were the least for subtest 3, 4, and 5. A comparison of the mean scores across the groups revealed that the bilingual group obtained higher mean scores on all the subtests which indicated that the bilingual group performed better than the monolingual group on all the verbal and nonverbal subtests. The mean scores of both the groups on each of the subtests were subjected to independent t- test. The results obtained revealed that there was a significant difference between the monolingual group and the bilingual group at 0.01 level for all the subtests except subtest 5 which was significant at 0.05 level. The t- values have been depicted in Table 1. The performance of the two groups on all the subtests has also been depicted in Figure 2.

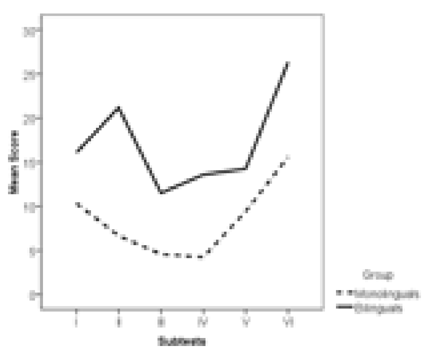

Figure 2*: Performance of both the groups across various subtests of creativity.*

Discussion

The results of the present study revealed that bilingual Kannada English adolescents attained higher scores on all subtests than monolingual Kannada speaking adolescents. This reflects the influence of knowing and using two languages on the creative abilities of the participants. Similar results were obtained by Peal and Lambert (1962), Balkan (1970), Cummins and Gulutsan (1974), Landry (1974), Bruck, Lambert, and Tucker (1976), Ben-Zeev (1977a), Ricciardelli, (1992a; 1992b); Kormi-Nouri, Moniri, and Nilsson (2003), Simonton (2008), and Kharkhurin (2008, 2009). Scott (1973) also reported in his study that the bilinguals have a greater degree of divergent thinking. The study by Kessler and Quinn (1987) revealed that bilingual children performed better on problem solving task than their monolingual counterparts. They interpreted these results as evidence of greater metalinguistic competence and better developed creative process. Studies by Torrance Gowan, Wu, and Aliotti (1970) also have reported that bilingual children show greater originality in creative thinking.

However the results of the present study are not in agreement to the studies by Okoh (1980) who found that there was a significant difference between bilingual children and their monoglot counterparts only on the verbal creativity tests and not on the nonverbal creativity tests and with Kharkhurin (2010a) who found that the monolinguals were better than bilinguals on verbal creativity measures. Stephens, Advisor, Esquivel, and Giselle (1997) also found that the bilingual children did not outperform their monolingual counterparts in the area of creativity.

Bilinguals can comprehend a problem in a number of different ways. The linguistic experience for the bilinguals in the two different languages could aid in this process. The encoding and assessing of concepts and knowledge could be carried out in varied ways. This could have led to the superior performance of the bilingual group in subtests such as the seeing problems test and the consequences test.

Bilinguals can store the same concepts in different linguistic networks. This diversity of association is assumed to be a vital property of creative thinking. This helps to link unrelated concepts from different categories and think differently. This advantage could have helped the bilinguals to perform better on subtests such as the unusual uses test and the test of inquisitiveness compared to monolinguals. Bilingualism facilitates the innovative capacity to generate new ideas and concepts (Kharkhurin, 2009). This could have contributed to superior performance of bilinguals in tests such as completion of figure and draw the person.

Cummins (1976) explained some possible beneficial links between bilingualism and creative thinking. The first explanation is that bilinguals have a wider and more varied range of experiences than monolinguals because they operate in two languages and possibly in two cultures. The second explanation concerns a switching mechanism. Because bilingual children must switch from one language to another, they may be more flexible in thinking. The third explanation is based on the process of objectification (Cummins & Gulustan, 1974). Bilinguals may be involved in a process of comparing and contrasting two languages, seeking varying language rules and differentiating between word sounds and word meanings.

The repeated switching from one language to another and constant dealing with the two code systems (phonological, phonetic and lexical) may facilitate their metalinguistic awareness which presumably facilitates their cognitive abilities (Pattnaik & Mohanty, 1984; Bialystok, 1988; Galambos & Goldin-Meadow, 1990; Mohanty, 1992). Moreover both cross linguistic and cross cultural experiences could possibly result in the modification in the memory and its structure (Kormi-Nouri et al., 2003). This specific structure may facilitate the diversity of association in bilinguals, because the same concept is linked to two different linguistic codes for conceptual network.

Further the difference in performance could also be attributed to the bilateral hemisphere involvement for language processing in bilinguals (Vaid & Hull, 2002) and the greater density of grey matter in their brain (Mechelli et al., 2004). The results of the present study also extend support to the LMCA model given by Kharkhurin (2009).

Conclusions

The current study was aimed to investigate the creative thinking abilities of bilingual and monolingual adolescents. A total of 24 participants (12 monolinguals and 12 bilinguals) were a part of the study. Four verbal subtests from the Passi test of creativity and two other nonverbal subtests of creativity developed by Veena and Bhavani (2002) were administered on the selected participants. The important finding of the present study was that bilinguals outperformed the monolinguals in all the verbal and nonverbal subtests of creativity which indicated that the bilinguals were more creative than monolinguals. There was a definite advantage of bilingualism on the creative abilities of the individuals considered in the study. Their cross linguistic experience helped them to encode knowledge and think in flexible and divergent ways. However, caution must be taken while generalizing the results to other bilingual population given the number of participants considered for the study. Nevertheless, the study has important implications. The results of this study help us to refine our understanding of bilingual individuals and may contribute towards eradicating the notion in people's mind that bilingualism hampers the development of the individual in all domains. The positive relations found between bilingualism and creativity emphasizes the importance of bilingual education which would lead to the evolution of more creative and productive citizens for the country. This study has some clinical implications too. If the children with communication disorders are potential enough, they also should be made proficient in two languages thus consequently enhancing their creativity.

However, there is a need for more comparative and cross linguistic studies on various types of bilinguals. A longitudinal study of such individuals also could throw light into the pattern of cognitive changes that occur with respect to time. Further, it would also be interesting to study creativity in the communication disordered population.

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References

Balkan, L. (1970). *Les effets du bilinguisme Francais-anglais sur les aptitudes intellectuelles* Bruxelles: Aimav**.**

Ben-Zeev, S. (1977a). The effect of Spanish English bilingualism in children from less privileged neighborhoods on cognitive development and strategy. *Working papers on bilingualism, 14,* 83-122.

Ben-Zeev, S. (1977b). The influence of bilingualism on cognitive strategy and development. *Child Development, 48,* 1009-1018.

Bialystok, E. (1988). Levels of bilingualism and levels of linguistic awareness. *Developmental Psychology, 24*(4), 560-567. from PsycINFO database.

Bialystok, E. (1991). Metalinguistic dimensions of bilingual language proficiency. In. E. Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development, 70,* 636-644.

Bialystok, E. (2001). *Bilingualism in development: Language, literacy, and cognition.* New York Cambridge University Press.

Bialystok, E. (2005). Consequences of bilingualism for cognitive development. In F. Kroll & A. M. B. De Groot (Eds.), Handbook of bilingualism: Psycholinguistic approach (pp. 417–432). Oxford, UK: Oxford University Press.

Bruck, M., Lambert, W. E., & Tucker, G. R. (1976). Cognitive consequences of bilingual schooling: The St. Lambert project through grade six. *Linguistics, 24,* 13–33.

Cummins, J. (1976). The influence of bilingualism on cognitive growth: A synthesis of research findings and explanatory hypothesis. *Working Papers on Bilingualism,9,* 84-93.

Cummins, J. (1978). Bilingualism and the development of metalinguistic awareness. *Journal of Cross-Cultural Psychology*, 9, 131-149.

Cummins, J., & Gulutsan, M. (1974). Some effects of bilingualism on cognitive functioning. In. S. T. Carey (Eds.)., *Bilingualism, Biculturalism, and Education.* Proceedings of the conference at college universitaire Saint-Jean, The University of Alberta, Canada.

Duncan, S. E., & De Avila, E. A. (1979). Bilingualism and cognition: Some recent findings. *National Association for Bilingual Education Journal, 4,* 15–50.

Galambos, S. J., & Goldin-Meadow, S. (1990). The effects of learning two languages on levels of metalinguistic awareness. *Cognition, 34*(1), 1-56. from PsycINFO database.

Grosjean, F. (1998). Studying bilinguals: Methodological and conceptual issues. *Bilingualism: Language and Cognition, 1 (2),* 131-149.

Guilford, J. P. (1967). The nature of human intelligence. New York, NY: McGraw-Hill.

Hakuta, K. (1986). *Mirror of language: The debate on bilingualism.* NewYork Basic Books.

Ianco-Worall, A. (1972). Bilingualism and cognitive development: *Child Development, 43*, 1396-1460.

Ingram, E. D. (1985). How native like? Measuring language proficiency in bilinguals. *Journal of Applied Linguistics, XI* (2), 47-64.

Kasof, J. (1997). Creativity and breadth of attention. *Creativity Research Journal, 10(4),* 303-315.

Kessler, C., & Quinn, M. E. (1987). Positive effects of bilingualism on science problem-solving abilities. In J. E. Alatis (Ed.), Current issues in bilingual education: Proceedings of the Georgetown roundtable on languages and linguistics (pp. 295–308). Washington, DC: Georgetown University Press.

Kharkhurin, A. V. (2008). The effect of linguistic proficiency, age of acquisition, and length of exposure to a new cultural environment on bilinguals' divergent thinking. *Bilingualism: Language and Cognition, 11 (2),* 225-243.

Kharkhurin, A. V. (2009). The role of bilingualism in creative performance on divergent thinking and Invented Alien Creatures tests. *Journal of Creative Behavior, 43,* 59–71.

Kharkhurin, A. V. (2010a). Sociocultural differences in the relationship between bilingualism and creativity potential. *Journal of Cross-Cultural Psychology, 41,* 776–783.

Koestler, A. (1964). *The act of creation.* Lewiston, NY: Macmillan.

Kormi-Nouri, R., Moniri, S., & Nilsson, L. (2003). Episodic and semantic memory in bilingual and monolingual children. *Scandinavian Journal of Psychology, 44(1),* 47-54.

Kroll, J. F., & de Groot, A. M. B. (1997). Lexical and conceptual memory in the bilingual: Mapping form to meaning in two languages. de Groot & Kroll (Eds.), pp. 169-199.

Landry, R. G. (1973). The enhancement of figural creativity through second language learning at the elementary school level. *Foreign Language Annals, 7*(1), 111-115. from Linguistics and Language Behavior Abstracts database.

Landry, R. G. (1974). A comparison of second language learners and monolinguals on divergent thinking tasks at the elementary school level. *Modern language Journal, 58*, 10-15.

Leikin, R. (2009). Exploring mathematical creativity using multiple solution tasks. *Creativity in mathematics and the education of gifted students.* In R. Leikin, A. Berman, & B. Koichu (Eds.) (pp. 129–145). Rotterdam, Netherlands: Sense Publishers.

Mechelli, A., Crinion, J., Noppeney, U., O'Doherty, J., Asburner, J., Frackowiak, R., & Price, C. (2004). Structural plasticity in the bilingual brain. *Nature, 431*, 757- 785.

Mednick, S. A., & Mednick, M. T. (1967). *Examiner's manual: Remote Associates Test.* Boston: Houghton Mifflin.

Mendelsohn, G. A. (1976). Associative and attentional processes in creative performance. *Journal of Personality, 44(2),* 341-369.

Mohanty, A. K. (1992). Bilingualism and cognitive development of kond tribal children: Studies on metalinguistic hypothesis. *Pharmacopsychoeco-logia.Special Issue: Environmental Toxicology and Social Ecology, 5*(1-2), 57-66. from PsycINFO database.

Mumford, M. D., Mobley, M. I., Uhlman, C. E., Reiter-Palmon, R., & Doares, L. M. (1991). Process analytic models of creative capacities. *Creativity Research Journal, 4(2),* 91-122.

Okoh, N. (1980). Bilingualism and divergent thinking among Nigerian and Welsh school children. *Journal of Social Psychology, 110,* 163–170.

Pattnaik, K., & Mohanty, A. K. (1984). Relationship between metalinguistics and cognitive development of bilingual and unilingual tribal children. *Psycho-Lingua, 14*(1), 63-70. from PsycINFO database.

Passi, B. K. (1979). *Tests of Creativity*. Agra National Psychological corporation.

Peal, E., & Lambert, W. E. (1962). The relation of bilingualism to intelligence. *Psychological Monograph, 76*, 1-23.

Ricciardelli, L. A. (1992a). Bilingualism and cognitive development in relation to threshold theory. *Journal of Psycholinguistic Research, 21,* 301–316.

Ricciardelli, L. A. (1992b). Bilingualism and cognitive development: A review of past and recent findings. *Journal of Creative Behavior, 26,* 242–254.

Saul, M., & Leikin, R. (2010). Intercultural aspects of creativity: Challenges and barriers. *Mediterranean Journal for Research in Mathematics Education, 9,* 1–9.

Scott, S. (1973). *The relation of divergent thinking to bilingualism. Cause or effect?* Unpublished research report. McGill University.

Simonton, D. K. (2008). *Bilingualism and creativity. An Introduction to bilingualism: principles and processes.* J. Altarriba & R. R. Heredia (Eds.), (pp. 147-166). NJ: Erlbaum.

Singhi, P., Kumar, M., Malhi, P., & Kumar, R. (2007). Utility of the WHO ten questions screen for disability detection in rural community - the North Indian experience. *Journal of Tropical Pediatrics, 53* (6), 383-387.

Sosa, A. L., Albanese, E., & Prince, M. (2009). Population normative data for the 10/66 Dementia Research Group cognitive test battery from Latin America, India and China: a cross-sectional survey, *BMC Neurology*, 9:48;1471-2377.

Stephens., Advisor, A. M., Esquivel., & Giselle, B. (1997). *Bilingualism, creativity, and social problem solving.* Fordham University.

Torrance, E. P. (1966). *Torrance tests of creative thinking*. Princeton, NJ: Personnel Press.

Torrance, E. P. (1974). *Torrance tests of creative thinking: Directions manual and scoring guide*. Lexington, MA: Ginn.

Torrance, E. P., Gowan, J. C., Wu, J. J. & Aliotti, N. C. (1970). Creative functioning of monolingual and bilingual children in Singapore. *Journal of Educational Psychology, 61 (1),* 72-75.

Tranter, L. J., & Koutstaal, W. (2008). Age and flexible thinking: An experimental demonstration of the beneficial effects of increased cognitively stimulating activity on fluid intelligence in healthy older adults. *Aging, Neuropsychology, and Cognition, 15,* 184–207.

Vaid, J., & Hull, R. (2002). Re-envisioning the bilingual brain using functional neuroimaging: Methodological and interpretive issues. In F. Fabbro (Ed.), *Advances in the neurolinguistics of bilingualism*: A festschrift for Michel Paradis (pp. 315-355). Udine, Italy Forum.

Veena, K., & Bhavani, A. D. (2002). Creativity in hearing impaired and normals. *Student research at AIISH Mysore (articles based on dissertation done at AIISH), Vol:1,*138-139.

Venkatesan, S. (2009). Readapted from 1997 Version. *NIMH Socio Economic Status Scale*. Secunderabad: National Institute for the Mentally Handicapped.

Vygotsky, L. (1986). *Thought and language*. Cambridge, MA MIT press.

Ward, T. B., Smith, S. M., & Vaid, J. (1997). *Creative thought: An investigation of conceptual structures and processes*. Washington, D.C.: American Psychological Association.

FIELD TESTING OF MANUAL FOR ADULT: NON-FLUENT APHASIA THERAPY IN KANNADA (MANAT-K)

[1]Goswami S. P., [2]Jayashree C. Shanbal, [3]Samasthitha S. & [4]Navitha U.

Abstract

The treatment of people with aphasia requires systematic approach for facilitation of recovery. Persons with aphasia exhibit divergent symptoms which vary according to the type and severity of aphasia. Use of culturally relevant material plays a vital role for bringing about heightened progress which results in effective generalization. It is also important to chart the progress in a systematic manner to contribute towards evidence based practice. Hence, there is a need to develop a manual which provides structured activities for persons with various types of aphasia. This manual is an outcome of the field tested project MANAT-K. The results of the study have shown that the performance of the ten participants with non-fluent aphasia using MANAT-K improved in its various domains i.e. functional communication, repetition, comprehension and expression, naming and reading and writing.

Key words: C*linical, adult language, skills*

Aphasia is described as a "multimodality reduction in the capacity to decode (interpret) and encode (formulate) meaningful linguistic elements. It is manifested as difficulties in listening, reading, speaking and writing'' (Darley, Aaronson & Brown, 1975, as cited in Benson & Ardila, 1996).

The management of persons with aphasia is a complicated task that involves the coordinated efforts of a rehabilitation team representing several disciplines. The speech language pathologist (SLP) being one of the key members of the team, faces a number of challenges while planning the management program for persons with aphasia. The reason is mainly due to the varied nature of the disorder, manifesting impairment in all the aspects of language. Thus, it has been stated by the researchers that the speech language pathologists must use language treatment programs that have been described in detail and proved to be effective (Shewan & Bandur, 1986). There are various authors who have proposed a number of therapy techniques for the treatment of non-fluent aphasia such as Language Orientated Treatment, Helm Elicited Program for Syntax Stimulation, Response Elaboration Training and so on. However, the effectiveness of these techniques depends on the usage of the linguistic material. Thus, it is important that the treatment programs are tailor made to suit the needs of a person with aphasia.

Authors have proposed a number of therapy techniques and manuals for the treatment of aphasia but, majority of them refer to the Western population (English language), for example, the Manual for Aphasia Therapy developed by Longerich (1968), An Auditory and Verbal Task Hierarchy by Ross and Spencer (1980). In the Indian context, Manual for Adult Non-Fluent Aphasia Therapy- in Hindi (MANAT-H, Deshpande & Goswami, 2004), Manual for Adult Non-Fluent Aphasia Therapy- in Kannada (MANAT-K, Venugopal & Goswami 2005) have been developed. These manuals have focused mainly on developing materials for therapy purposes, but have not been field tested. By using a field tested manual, speech language pathologists can provide better and effective rehabilitation for persons with aphasia. Hence, a need was felt to field test the Manual for Adult Non-Fluent Aphasia Therapy- in Kannada.

The Manual for Adult Non-fluent Aphasia Therapy in Kannada (MANAT-K) consists of five broad domains. Therefore, the review of literature is discussed under the headings of these five domains- Functional communication, repetition, comprehension and expression, naming reading and writing domain.

Functional communication domain

Functional communication problems in different areas like language, behavioral and physical skills lead to restrictions in social involvement. Consequences of difficulty in communication can impinge on their participation in society and may lead to social isolation, mental and emotional changes (behavioral problems like depression, apathy), problems in adjustments of

[1]Professor in Speech Pathology, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: goswami16@yahoo.com, [2]Lecturer in Language Pathology, AIISH, Mysore-06, Email: jshanbal@gmail.com, [3]Houston, USA & [4] Speech Language Pathologist, SRMU, Chennai

interpersonal relations, lack of independence and failure to return to their workplace (Cruice, Worrall, Hickson & Murison, 2003).

Treatment should focus on "bridging language skills and adaptations into the real-life needs of the person with aphasia" (La Pointe, 2005). The treatment for aphasia by the speech-language pathologists often depend on the needs and preferences of persons with aphasia and their family members, the time (post-onset of stroke) and other variables which will vary from individual to individual. It is essential that the speech-language pathologist incorporate these tasks which are functional for each person with aphasia. For example, a bank employee may be given a word retrieval task which requires him to name various activities needed for his job.

Repetition domain

Repetition refers to the ability to reproduce patterns of familiar speech sounds from the auditory presentation. It is the most elementary mechanism at the core of spoken language. Goodglass and Kaplan (1983) reported that repetition phenomenon in persons with aphasia could be distributed at three points in the process- may fail at the level of recognition or, may fail to grasp the sounds as words, failure at the level of articulation in spite of a person's ability to demonstrate that the person knows the meaning of the test word and finally failure due to selective disassociation between auditory input and speech output system.

Comprehension and Expression domain

It is observed that the auditory comprehension is better preserved in persons with non-fluent aphasia in comparison to the fluent type. Comprehension is relatively better than the verbal output. Comprehension deficits in persons with non-fluent aphasia can range from difficulty in comprehending a specific sequence of commands, pointing to a serially named object/picture. They might often have difficulty in understanding of syntactic structures and words omitted in the verbal output are difficult to comprehend Caplan and Hildebrandt (as cited in Benson & Ardila, 1996). Comprehension of spoken language is usually considered to be good in persons with transcortical motor aphasia at least at the level of routine conversation. There might be some difficulty in complex material and relational words Rothi and Heilman, (as cited in Benson & Ardila, 1996). Similar reports of obvious comprehension and expression deficits have been stated by Caramazza, Capasso, Capitani and Miceli (2005), Goodglass and Berko (as cited in Benson & Ardila, 1996), Hence, it was important to incorporate the various activities to improve the auditory comprehension skills.

Naming domain

Naming is a major speech production target for most persons with aphasia. Hence, treatment for naming deficits depends on the type of errors presented by a person with aphasia. Generally, persons with frontal lobe lesions including the Broca's area present with word production anomia. This type results from motor problems that are consequence of the anterior lesions. This type of word production anomia is further classified into several types. *Articulatory reduction anomia* is most commonly found in persons with Broca's aphasia. Due to the reduction in articulatory competency, naming problems arise which is characterized by deletion of syllables in clusters and phonemic assimilation.

Howard, Patterson, Franklin, Orchard-Lisle, and Morton (1985 b) conducted a study on 12 persons with acquired aphasia who demonstrated word-finding deficits. They compared the effect of two therapy techniques in the treatment of picture naming deficits. The two therapy techniques were semantically and phonologically-based treatments and each participant took part in both types of treatments. The participants, for each technique, either attended four sessions per week or eight sessions per two weeks. Results indicated that after one week following the end of the treatment, significant amount of improvement was reported for semantic therap. The researchers attributed this to the improvement that generalized to the untreated items. They have concluded that precise and theoretically driven therapy methods will bring about significant improvement in the word retrieval abilities in persons with aphasia. Henaff Gonon, Bruckert and Michel (1989), Kiran and Bassetto (2008) have also emphasized the importance to improve naming deficits in persons with aphasia

Reading and writing domain

In persons with non-fluent aphasia reading deficits may present itself as a difficulty (often total failure) in reading aloud. Most of the persons with non-fluent aphasia (especially the Broca's aphasia) have difficulty in comprehending written material (as cited in Benson & Ardila, 1996). However, reading comprehension may be better preserved than reading aloud. On the other hand, persons with transcortical motor aphasia both reading aloud and comprehension is better preserved than their writing skills. Also the reading comprehension is reported to be at near normal levels except for syntactically complex materials.

Reading and writing deficits may be more or less important for a person with aphasia. Hence, the clinician working to improve one's reading and writing skills should take in to consideration the pre-morbid literacy level, current need and interest in reading and writing.

To sum up, from the literature reports one can derive that the persons with aphasia exhibit deficits in various linguistic domains. Thus, it is of utmost importance that speech language pathologists plan activities using materials/ stimuli which are field tested and are directed to improve the skill deficit areas.

Method

The present study aimed at field testing the Manual for Adult Non-Fluent Aphasia Therapy-in Kannada (MANAT-K. A total of ten persons with non-fluent aphasia served as participants for the study. Persons with aphasia were identified through hospitals, neurological clinics and/ or speech and hearing institutes/centers. They were diagnosed using adapted version of Western Aphasia Battery in Kannada (Chengappa & Vijayashree, 2007) by experienced speech language pathologist. The age range of the participants ranged from 28-73 years with a mean age of 51.4 years. The non-fluent aphasia group consisted of one person with global aphasia, six persons with Broca's aphasia and three persons with trans-cortical motor aphasia. Participants were selected by adhering to the appropriate ethical procedures. Participants and the family members were explained about the purpose and procedures of the study, and an informed verbal and/or written consent was taken.

All participants were native speakers of Kannada and had aphasia following stroke and the lesion was confined to left hemisphere. There was no known history of pre-morbid neurological illness, psychiatric disorders and/or cognitive decline, and no other significant sensory and/or cognitive deficits. The demographic details of the participants are presented in Table 1.

Procedure

The present study was carried out in two phases.

Table 1: *Demographic details of persons with aphasia.*

Sl.No	Age (years)	Gender	Time Post Onset	Type of aphasia	Pre-morbid vocation
1	65	Male	Seven months	Global aphasia	Business
2	40	Male	Eight months	Broca's aphasia	Auto driver
3	28	Male	Three years	Broca's aphasia	Animation designer
4	52	Male	11 months	Broca's aphasia	Factory worker
5	56	Male	Four years	Trans-cortical motor aphasia	Bank employee
6	49	Male	Six months	Broca's aphasia	Bank employee
7	46	Male	Four months	Broca's aphasia	Daily wager
8	73	Male	Three months	Trans-cortical motor aphasia	Retired Sub-Inspector of Police
9	45	Male	Eight months	Broca's aphasia	Bus Driver
10	60	Male	One month	Trans-cortical motor aphasia	Group D employee

The phase I included reviewing the Manual for Adult Non-fluent Aphasia Treatment in Kannada (MANAT-K). This manual was developed by Venugopal and Goswami (2004). Phase II included the field testing of the MANAT-K. In this phase persons with non-fluent aphasia were given treatment using this manual. Each participant attended a total of 15 speech and language therapy sessions, each session lasting for duration of 45 minutes.

Phase I: Modification of the Manual: Preparation of stimuli

Manual for Adult Non-fluent Aphasia Treatment in Kannada (MANAT-K) by Venugopal and Goswami (2004) was reviewed. After reviewing MANAT-K (2004), the documented principles and guidelines prescribed in the literature for the treatment of persons with non-fluent aphasia were compiled and organized. The illustrations of various activities in the different domains were based on the principles of aphasia management. The activities of each sub-section have been arranged in hierarchical order along with its stimulus and response mode hierarchy. Scoring pattern and progress criteria are provided in the beginning of each sub-section. Overall progress criterion is also provided for each domain and its sub-sections. The following broad domains were finalized-Functional communication (FC), repetition (R), comprehension and expression (C&E), naming (N) and reading and writing (R&W). Each of these domains is further sub-divided into several sub-sections.

Table 2: *Responses of the judges regarding the manual.*

Sl. No	Parameters	Very Poor	Poor	Fair	Good	Excellent
1	Simplicity			1	9	2
2	Familiarity			2	7	3
3	Size of the picture			2	5	5
4	Color and appearance			5	2	5
5	Arrangement			4	5	3
6	Presentation		2	2	8	
7	Volume			3	8	1
8	Relevancy				9	3
9	Complexity			3	7	2
10	Iconicity			5	6	1
11	Accessibility			4	6	2
12	Flexibility				8	4
13	Trainability			1	4	7
14	Stimulability			1	7	4
15	Feasibility			1	8	3
16	Generalization		2	3	4	3
17	Scope of practice			2	6	4
18	Scoring Pattern			7	3	2
19	Publications, Outcomes and Developers (professional background) *	Yes No	2 10			
20	Coverage of parameters (Reception and expression)			1	9	2

**The SLPs were asked to rate this parameter in terms of "Yes" or "No"*

Stimuli and activities incorporated in MANAT-K under the above mentioned sections were framed keeping in mind the semanticity, familiarity and usage. Appropriate picture stimuli wherever necessary for the manual were drawn by a professional artist. A feedback rating questionnaire (Appendix I) was developed containing 20 parameters, consisting of a 5-point rating scale in order to rate the stimuli and activities illustrated in the various sub-sections of modified MANAT-K. Twelve Speech Language Pathologists (SLPs) who were native speakers of Kannada were asked to judge the manual based on this feedback questionnaire. The responses of the judges about the manual are shown in Table 2.

There were few other suggestions given by the SLPs regarding the correction of syntactic structures/sentence formation to be followed in Kannada, clarity and color of the topic representation in the picture stimuli, arrangement of stimuli in random order under the "tenses" section of "syntax level". The suggestions given by the judges were incorporated and a final form of MANAT-K was prepared.

Additionally, to get a feedback about the expediency of the manual from the caregivers of the participants, a feedback questionnaire was developed. This questionnaire was distributed to them at the end of the 15th therapy session.

Phase II: Field testing

In phase II, the field testing of MANAT-K was carried out. Ten persons with different types of non-fluent aphasia (one-global; six-Broca's and three-trans-cortical motor aphasia) were subjected to MANAT-K. Using this manual, speech-language therapy was given by a speech language pathologist for 15 sessions each session lasting for duration of 45 minutes. Though the total participants were ten, but all of them were not subjected to all the domains, as few persons with aphasia performances were very poor mainly for naming and repetition skills. Thus, in few domains of MANAT-K, the participants number was less than ten.

However, during the speech language therapy sessions, a need was felt to incorporate tailor made activities for each person with non-fluent aphasia, since the group was heterogeneous in nature. Hence, additional activities were integrated in the manual to provide a broader view keeping in mind some other deficits. These included treatment for Apraxia of Speech (AOS) - Eight Step Continuum (Rosenbek et al. 1973), Oro-motor exercises, written alphabet and word cards (for each stimulus) and individual picture cards

Response and recording

Each session of speech language therapy was video recorded. The video recorded sample was analyzed for the number of correct, partial/intelligible and incorrect/no responses for each participant in different sub-sections of MANAT-K. A score of '1', '1/2' 'and '0' was given for every correct, partial/intelligible and incorrect/no responses respectively. The raw scores of each participant for different activities were converted to percentage. Further these scores were subjected to statistical analysis using SPSS software (version16.0) package.

Results

The findings of the present study based on the statistical analysis have been broadly presented under the following headings:

Quantitative analysis of performances by all persons with non-fluent aphasia (N=10) across various domains

a) Comparison of performances of persons with non-fluent aphasia on functional communication (FC) domain for the pre, mid and post therapy sessions (i.e. 1st, 7th and 15th session)

The overall total scores were summed up for all the activities of the sub-sections under functional communication domain. The mean (M) and standard deviation (SD) for pre, mid and post therapy sessions were calculated for ten persons with non-fluent aphasia. Table 3 illustrates the mean and SD values for persons with non-fluent aphasia for functional communication domain.

Table 3: *Mean and SD values for persons with non-fluent aphasia for functional communication domain*

	Functional communication		
	Pre therapy session	Mid therapy session	Post therapy session
Mean (N=10)	53.01	62.32	71.27
SD	19.21	13.86	14.25

From Table 3, it can be seen that the ten participants scored an overall mean of 53.01 (SD =19.21), 62.32 (SD =13.86) and 71.27 (SD =14.25) in pre, mid and post therapy sessions respectively across the various sub-sections in functional communication domain.

Results showed that there was a difference in the performances in functional communication domain across the pre, mid and post therapy sessions as evident from the mean score values. As the mean score values differed across three sessions, the Friedman's test was carried out to identify any statistically significant difference in the pre, mid and post therapy sessions.

A significant difference was obtained in pre, mid and post therapy session {χ^2 (2) = 19.54, $p<0.01$}, the data was further subjected to Wilcoxon signed rank test. Results of this test indicated a significant difference between pre and mid ($|z|= 2.66$, $p<0.01$); mid and post ($|z|= 2.81$, $p<0.01$) and pre and post ($|z|= 2.80$, $p<0.01$).

Thus, it is obvious from the results that the activities stated in manual have shown improvement in the communication skills at functional level in persons with non-fluent aphasia. The treatment for aphasia often depends on the needs and preferences of persons with aphasia and their family members which will vary from one person to the other. It is imperative that the speech-language pathologists incorporate tasks which are functional in nature, keeping in mind the assets of an individual with aphasia. For example, a bank employee may be given a word retrieval task which requires him to name various activities needed for his job. Evidence comes from the research work by La Pointe, 2005, who reported that treatment should focus on "bridging language skills and adaptations into the real-life needs of the person with aphasia". Thus, the activities mentioned under the functional domain of MANAT-K facilitate the persons with aphasia to relearn the activities of daily living and thereby enhancing a person's participation in communication. Therefore, indirectly or directly the communication skills which were lost in a person with aphasia can be strengthened using the various activities stated in the functional domain of MANAT-K, which inturn improves the quality of life. Researchers like Cruice, Worrall, Hickson and Murrison (2003) have reported that it is imperative that the skills of persons with aphasia in the area of language functioning, functional communication, emotional and social health, and physiological well being are critical aspects which professionals should consider while planning their rehabilitation program.

b) Comparison of performances of persons with non-fluent aphasia on repetition domain for the pre, mid and post therapy sessions (i.e. 1st, 7th and 15th session)

From Table 4, it can be seen that the ten participants scored a mean of 51.53 (SD =24.64), 60.17 (SD=23.05) and 63.36 (SD =20.40) in pre, mid and post therapy sessions respectively across the various sub-sections in functional communication domain.

It was observed that the results showed that there was significant difference in the mean scores. Therefore, the data was further analysed using Friedman's test. The results showed a significant difference in pre, mid and post therapy session {χ^2 (2) =11.52, $p<0.05$}. No obvious difference between pre and mid and mid and post therapy sessions on Wilcoxon signed rank test. However, statistically significant difference of ($|z|= 2.66$, $p<0.01$) was evident in the pre and post therapy session on repetition domain of MANAT-K.

The results have clearly shown that activities under equivocal (yes/no), egocentric, automatic speech and environmental stimuli are arranged in such a way that appropriate responses from persons with non-fluent aphasia can be elicited and an improvement in the communication skills

Table 4: *Mean and SD values for persons with non-fluent aphasia for repetition domain.*

	Repetition		
	Pre therapy session	Mid therapy session	Post therapy session
Mean (N=9)	51.53	60.17	63.36
SD	24.64	23.05	20.40

becomes evident over a period of time. Though, typically repetition is an important aspect to improve the communication skills, these repetition tasks needs to be integrated with the activities involved in improving the auditory comprehension and expression. Further, repetition tasks juxtaposed with the traditional aphasia therapy techniques like Melodic Intonation Therapy, Context-based approach, Response elaboration technique etc. facilitate the sub-vocal rehearsals which inturn helps a person with non-fluent aphasia to monitor their comprehension and expressive skills. Thus, it can be stated that the activities mentioned under repetition tasks in MANAT-K does facilitate the verbal communication skills. Therefore, the activities in this task can either be carried out independently depending on the repetition skills of a person or can be integrated along with other tasks. Thus, the activities illustrated under this domain have shown that they are flexible enough to bring a change in the verbal output. This is evident from the performance of all the participants including the person with global aphasia.

c) Comparison of performances of persons with non-fluent aphasia on comprehension domain for the pre, mid and post therapy sessions (i.e. 1st, 7th and 15th session)

Table 5 illustrates the mean and SD values of the ten participants who scored a mean of 57.22 (SD =24.24), 63.95 (SD=23.26) and 65.11 (SD=20.19) in pre, mid and post therapy sessions respectively across the various sub-sections in comprehension domain.

The Friedman test was further carried out which revealed that there was no significant difference across pre, mid and post therapy sessions. The performances of all the participants with non-fluent aphasia across the various activities were not statistically significant, but the mean values did show a difference across the sessions. This indicates that persons with non-fluent aphasia did show an improvement in this domain which is relatively better in the post therapy sessions in

Table 5: *Mean and SD values for persons with non-fluent aphasia for comprehension domain.*

	Comprehension		
	Pre therapy session	Mid therapy session	Post therapy session
Mean (N=10)	57.22	63.95	65.11
SD	24.24	23.26	20.19

comparison to the pre therapy sessions. The improvement shown reflects that the activities illustrated in the manual did bring about a gradual and steady progress in this domain.

Evidence also comes from the research work done by Caramazza, Capasso, Capitani and Miceli, 2005 who reported that there seems to be no simple forms of impairment of comprehension in persons with Broca's aphasia and this they attributed to the variation of its comprehension level and large cognitive and linguistic heterogeneity in the task.

It is also proposed and advocated that using the present manual the clinician should present the stimulus with reduced rate, no background noise and with different types of cues (auditory, visual, gestural and orthographic) and gradually fading the cues as the therapy session progresses. For word comprehension, several variables can be manipulated to adjust difficulty. The lexical stimuli may be presented with the printed word. Redundant verbal context might help in identifying an object. Picture stimuli can be varied in semantic relatedness and can be supplemented with printed words. Therefore, the activities illustrated in the manual can also be varied for improving the comprehension of a person with non-fluent aphasia by manipulating the stimuli depending on the responses.

d) Comparison of performances of persons with non-fluent aphasia on expression domain for the pre, mid and post therapy sessions (i.e. 1st, 7th and 15th session)

The mean percentage values of the persons with non-fluent aphasia were compared across the pre, mid and post therapy sessions. The mean (M) and standard deviation (SD) were calculated by summing up the percentage scores obtained in the expression domain. These mean and SD values of are presented in Table 6. On this domain, the participants obtained a mean percentage of 49.06 (SD=16.77), 61.04 (SD=17.76), 63.12 (SD=14.20) respectively across the therapy sessions.

Table 6: *Mean and SD values for persons with non-fluent aphasia for expression domain.*

	Expression		
	Pre therapy session	Mid therapy session	Post therapy session
Mean (N=10)	49.06	61.04	63.12
SD	16.77	17.76	14.20

On the Friedman's test, it was observed that for all the 10 participants with non-fluent aphasia there was a significant difference [Pre-mid-post: {$\chi^2 (2) = 15.80, p<0.05$}] through the 1st, 7th and 15th sessions in the performance of expressive skills. Further Wilcoxon signed rank test revealed significant difference ($|z|= 2.80, p<0.01$) for pre and mid sessions and ($|z|= 2.80, p<0.01$) for pre and post therapy sessions. There was no statistically significant difference seen for mid and post therapy sessions. On the expression domain, all the participants showed substantial improvement from 1st to the 15th therapy sessions. This shows that the manual covers a wide range of activities which are framed to elicit the non-verbal as well as verbal responses from persons with non-fluent aphasia.

e) Comparison of performances of persons with non-fluent aphasia on naming domain for the pre, mid and post therapy sessions (i.e. 1st, 7th and 15th session)

The overall total mean percentage scores was obtained by compiling the percentage scores on different sub-sections for the naming domain for seven participants in the pre, mid and post sessions.

Table 7: *Mean and SD values for persons with non-fluent aphasia for naming domain.*

	Naming		
	Pre therapy session	Mid therapy session	Post therapy session
Mean (N=7)	50.59	56.91	63.32
SD	14.56	16.45	14.88

The overall mean scores achieved by the seven participants are presented in Table 7. The participants for the pre, mid and post therapy sessions obtained a score of 50.59 (SD=14.56), 56.91 (SD=16.45) and 63.32 (SD=14.88) correspondingly. Thus, the result showed a gradual trend in naming abilities of the participants from 1st to 15th session. This was supported by the findings of Friedman's test where a significant difference {$\chi^2 (2) =10.28, p<0.01$} was revealed. Subsequently the data was analyzed using Wilcoxon signed rank test which also showed a significant difference for pre and post and mid and post therapy sessions with ($|z|= 2.36, p<0.05$) and ($|z|= 2.02, p<0.05$) respectively. However, for the pre and mid sessions there was no significant difference. The results in this domain showed that there was an improvement in naming abilities in the 15th session in persons with Non-fluent aphasia. This typifies that the activities presented in the manual are stimulable for eliciting responses for the naming tasks. The stimulus presentation moved in hierarchy i.e. category specific to general naming.

Cueing strategies provided to the participants were also faded as the sessions progressed. This reveals that systematic presentation of stimuli and use of appropriate cueing techniques helps persons with non-fluent aphasia to improve their naming abilities. Also working on naming skills in persons with aphasia augments comprehension and expression abilities which in turn help the person to communicate better. This finding is in agreement from the study by researchers like Howard, Patterson, Franklin, Orchard-Lisle and Morton (1985b) and Horton and Byng (2000) who reported that the semantic therapy for anomia is well established both in research and in clinical practice. In addition, for the participant 8 and 10 orthographic cues were provided to elicit responses on the naming tasks, since sight-word reading was well preserved. This finding is in accord with the research report by Henaff Gonon, Bruckert and Michel (1989); Best, Hickin, Herbert, Howard and Osborne (2000) who have reported that orthographic cues have been proven to be effective in facilitating naming by persons with aphasia. Among the facilitation techniques used, the phonemic cue has been generally found to be the most efficacious, but its facilitating effect is short-lived (Patterson, Purell & Morton, 1983).

f) Comparison of performances of persons with non-fluent aphasia on reading and writing domain for the pre, mid and post therapy sessions (i.e. 1st, 7th and 15th session)

As the number of participants who were subjected to MANAT-K on the domain of reading and writing were limited (N=2), the data could not be analyzed using any objective statistical tests, the mean percentage score were calculated. It was observed that the mean percentage scores for participant 8 were 66.70, 65.00 and 67.13 for pre, mid and post therapy sessions respectively. For the 10th participant in the pre and mid therapy sessions the mean percentage scores were 71.67 and 79.76 respectively.

It was obvious that the activities taken up enhanced the reading and writing abilities, though the activities mentioned in the manual are very basic and focuses on day-to-day usage of such reading, writing and arithmetic skills.

Quantitative analysis of overall communication abilities in persons with non-fluent aphasia

The data collected from all the ten participants for the various domains on MANAT-K across pre, mid and post therapy sessions (1st, 7th and 15$^{th)}$ were summed up and analyzed and represented in the Table 8. The overall mean and standard deviation achieved by the persons with non fluent aphasia are 53.04 (SD=18.79), 60.50 (SD=16.67) and 64.37 (SD=14.69) for 1st, 7th and 15th therapy sessions respectively

Table 8: *Mean and SD values for overall communication skills in persons with non-fluent aphasia for various domains in MANAT-K across pre, mid and post therapy sessions.*

	Overall communication skills		
	Pre therapy session	Mid therapy session	Post therapy session
Mean (N=10)	53.04	60.50	64.37
SD	18.79	16.67	14.69

It is evident that there was a significant progress in the performance of the participants in overall communication skills as the therapy sessions moved from 1st to 15th. Non-parametric statistical analysis (Friedman's test) did reveal a significant difference [pre-mid-post: {χ^2 (2) = 14.60, $p<0.05$}], in the attainment of overall communication by non fluent aphasia. The Wilcoxon Signed Rank Test was further carried out which revealed a significant difference across pre-mid ($|z|= 2.49$, $p<0.05$), mid-post ($|z|= 2.39$, $p<0.05$) and pre-post ($|z|= 2.80$, $p<0.05$) therapy sessions.

It is also evident from the results that the person with global aphasia also showed obvious improvement in overall communication skills across the sessions. Hence, it can be stated that using MANAT-K, there was a noticeable trend in terms of improvement in overall communication skills of persons with non-fluent aphasia. This improvement was evident when the performances of the participants were compared for their performances across the various domains over the sessions.

This shows that MANAT-K paves way for speech-language pathologists to carry out the activities in a more methodological manner. The activities exemplified in the different sub-sections of the domains provide scope for flexibility and can be used by the clinicians at ease. The clinicians can use this manual along with the traditional therapy techniques used for enhancing communication abilities in persons with non-fluent aphasia. Further, it is also advocated in the manual that the cues play the role of catalyst and if used adequately and appropriately, will bring about the desired responses from persons with non-fluent aphasia hence making the clinical use of the manual more effective. Apart from the use of cues to elicit the responses from persons with non-fluent aphasia, there is also a provision to use other strategies such as vocal/sub-vocal rehearsals, self-correction, repetition, rephrasing, rate of stimulus presentation and speaking. Also using this manual appropriate feedback can be given for the person with non-fluent aphasia and also to their caregivers.

The sub-sections of the different domains cover a series of activities which can be carried out by the clinicians to fortify a wide range of responses from the persons with non-fluent aphasia. This manual also caters the needs of a person with aphasia whose verbal output is minimal (E.g.persons with global aphasia). Moreover, the strategies used in this manual also give way for the persons with non-fluent aphasia either to restore or compensate the lost communication skills. This view receives support from researchers namely Beukelman, Fager, Ball and Dietz, 2007.

Qualitative analysis of the clinicians' and care-givers' responses about the overall effectiveness of the treatment manual.

The 12 speech-language pathologists (SLPs) who rated the manual based on a feedback questionnaire as shown in Table 9. It is evident from the Table 9 that the two professionals rated the manual as "excellent" on the simplicity, complexity, accessibility scoring pattern and coverage of parameters. Familiarity, arrangement, relevance, feasibility and generalization were rated as "excellent" by three SLPs. The size of picture, color and appearance were rated as excellent by five SLPs. One professional rated the volume and iconicity parameter as "excellent". Flexibility, stimulability and scope of practice were graded as "excellent" by three professionals. Highest number (7) of SLPs rated the manual as "excellent" in terms of trainability.

Table 9: *Responses of the judges regarding the manual*

Sl. No	Parameters	Very Poor	Poor	Fair	Good	Excellent
1	Simplicity			1	9	2
2	Familiarity			2	7	3
3	Size of the picture			2	5	5
4	Color and appearance			5	2	5
5	Arrangement			4	5	3
6	Presentation		2	2	8	
7	Volume			3	8	1
8	Relevance				9	3
9	Complexity			3	7	2
10	Iconicity			5	6	1
11	Accessibility			4	6	2
12	Flexibility				8	4
13	Trainability			1	4	7
14	Stimulability			1	7	4
15	Feasibility			1	8	3
16	Generalization		2	3	4	3
17	Scope of practice			2	6	4
18	Scoring Pattern			7	3	2
19	Publications, Outcomes and Developers (professional background) *	Yes	2			
		No	10			
20	Coverage of parameters (Reception and expression)			1	9	2

**The SLPs were asked to rate this parameter in terms of "Yes" or "No*

Nine judges rated as "good" grade for simplicity, Relevance and coverage of parameters. Seven SLPs rated as "good" for familiarity, complexity and stimulability parameters. Five professionals rated as "good" on the size of the picture and arrangement parameters. Two professionals reported that the color and appearance were "good" in this manual. Eight SLPs judged the manual to be "good" on the presentation, volume, flexibility and feasibility parameters. Six judges rated the manual as "good" on iconicity, accessibility and scope of practice parameters. Trainability and generalization was rated as "good" by four judges. Three judges rated the scoring pattern as "good".

One professional rated the manual as "fair" on the simplicity, trainability, stimulability, feasibility and coverage of parameters. Two judges rated the familiarity, size of pictures, presentation and scope of practice parameters as "fair". Color and appearance, iconicity was rated as "fair" by five judges. Four SLPs rated the arrangement and accessibility as "fair". One judge rated the trainability, stimulability and feasibility and coverage of parameters as "fair". The rating "fair" was given by seven judges on scoring pattern parameter. However, only two professionals rated the presentation and generalization parameters as "poor". Also for the publications, outcomes and developers (professional background) domain, two professionals reported that they were aware of other materials available which can be used for improving language skills in persons with aphasia (i.e. UNICEF cards), and ten professionals stated that they were not aware of any other manuals available either in the Western or Indian contexts. Though, two professionals reported that UNICEF cards are available, these cards are not exclusively meant for persons with aphasia.

Consequently, it can be stated that this manual received grading ranging from excellent, good or fair from most of the judges. Therefore, the professionals were of the opinion that this manual can be used effectively on persons with non-fluent aphasia.

The caregivers of the persons with non-fluent aphasia were asked to give a feedback of the manual regarding its effectiveness on 10 parameters. It can be seen from the Table 10 that most of the caregivers rated the manual as "frequently" in the parameters listed, while few caregivers rated the manual as "most of the time" on the various parameters. All the caregivers stated that they were not using any other material to improve the communication skills for them.

Table 10: *Responses of the caregivers about the expediency of the manual MANAT-K.*

SL No	Parameters	Not at all	Sometimes	Frequently	Most of the time
1	Does this manual provide support and confidence to carry out activities at home?			8	2
2	Do you feel whether the activities in the manual are helpful and flexible to improve communication?			8	2
3	Does the manual provide better understanding of the ongoing treatment communication process?			9	1
4	Are the activities given in the manual in each section useful in different situations?			8	2
5	Are the activities and related items used in the manual familiar?			10	
6	Does the manual contain appropriate number of stimuli in each section?			7	3
7	Whether the picture stimuli are easily recognizable and representational?			9	1
8	Whether the manual is user-friendly and trainable?			10	
9	Whether the amount of effort and time involved in rehabilitation is satisfactory?			10	
10	Are you using any other training material(s) of the same kind? If yes how the materials used are different from each other?	10			

It can be inferred from the results that the feedback given by the speech-language pathologists ranged from "fair" to "excellent" about the manual. This reveals that professionals opined that this manual has good scope in terms of improving the communication skills in persons with non-fluent aphasia. Similarly the ratings from the caregivers of the participants indicated that the overall utility of the manual ranged from "frequently" to "most of the time" from the results. This shows that the caregivers found this manual quite useful bringing about an enhancement in communication skills.

Summary and Conclusions

The field tested results have shown that all the 10 persons with non-fluent aphasia did show improvement on various domains i.e. functional communication, repetition, comprehension, expression, naming, reading and writing. The improvement shown by persons with non-fluent aphasia reflects that this manual helps in improving various communication skills. The stimuli presented in the manual have been field tested and thus has proved to be effective in the management of persons with non-fluent aphasia.
Furthermore, it is also evident from the results that this manual is quite effective in eliciting responses even in persons with minimal/no verbal responses. Since the manual covers a wide range of activities covering different domains to improve linguistic skills, it provides scope for flexibility and the speech language pathologists can carry out the activities to elicit maximum responses from the person with non-fluent aphasia. Also, using this manual suitable feedback can be given to persons with non-fluent aphasia and also to their caregivers. In addition, it is emphasized to use this manual along with various traditional therapy techniques, appropriate cueing strategies as stated in the manual can bring about a difference in the communication skills in persons with non-fluent aphasia.

By using this field tested manual, it is expected that speech language pathologists can be provide better and effective rehabilitation for persons with aphasia. MANAT- K is quite handy for speech language pathologists who face the problem of using appropriate activities for improving various communication skills in persons with aphasia. This will facilitate the professionals in documentation of activities and responses in a scientific manner and make way for a better evidence based practice.

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References

Bacon, G.M., Potter, R, E., & Seikel, J.A (1992). Auditory comprehension of "Yes-No" questions by adult aphasics. *Journal of Communication disorders, 25* (1), 23-29.

Bandur, D. L., & Shewan, C.M. (1986). *Treatment of Aphasia. A Language-Oriented Approach*. London: Taylor & Francis Ltd.

Basso, A., Marangola, P., Piras, F., & Galluzi, C. (2001). Acquisition of new "words" in normal subjects: A suggestion for the treatment of anomia. *Brain and Language, 77*, 45-49.

Benson, D. F., & Ardila, A. (1996). *Aphasia. A Clinical Perspective.* New York: Oxford University Press.

Best, W., Hickin, J., Herbert, R., Howard, D., & Osborne, F. (2000). Phonological facilitation of aphasic naming and predicting the outcome of therapy for anomia. *Brain and language, 7,* 435-438.

Beukelman, D. R., Yorkston, K. M., & Dowden, P. A. (1985). Augmentative Communication: A casebook of clinical management. San Diego, CA: College Hill Press.

Beukelman, D., Fager, S., Ball, L., & Dietz, A. (2007). AAC for adults with acquired neurological conditions. *Augmentative and Alternative Communication, 23*, 230-242.

Caramazza, A., Capasso, R., Capitani, E., Miceli, G. (2005). Patterns of comprehension performance in agrammatic Broca's aphasia: a test of the Trace Deletion Hypothesis. *Brain language, 94*, 43-53.

Chaitra, S. & Goswami, S.P. (2010). *Manual for Adult Fluent Aphasia Therapy in Kannada (MAFAT-K). (Articles based on Dissertation done at AIISH), Part-B Speech Language Pathology, Vol VII:* 2008-2009, 62-66, All India Institute of Speech and Hearing, Mysore, India.

Chapey, R. (2008). *Language intervention strategies in aphasia and related neurogenic communication disorders.* Philadelphia, PA: Lippincott Williams & Wilkins.

Chengappa.S.K & Vijayashree (2008). *Normative & Clinical Data on the Kannada Version of Western Aphasia Battery (WAB-K)***.** Research project (WAB/ARF/ 3.35/07-08). All India Institute of Speech and Hearing Research Fund, Mysore, India.

Cruice, M., Worrall, L., Hickson, L. & Murison, R. (2003) Finding a focus for quality of aphasia: Social and emotional health, and psychological well-being. *Aphasiology, 17*, (4), 333-353.

Deshpande, R., & Goswami, S.P (2004) .*Manual for adult non-fluent aphasia therapy-in Hindi (MANAT-Hindi). (Articles based on Dissertation done at AIISH), Vol II:* 2003-2004, 189-193, All India Institute of Speech and Hearing, Mysore, India.

Garrett, K., & Lasker, J. (2005b). Adults with severe aphasia. In D. Beukelman & P. Mirenda (Eds.), Augmentative and alternative communication (3rd ed., pp. 467-504). Baltimore, MD: Paul H. Brooks.

Goodglass, H., & Kaplan, E. (1983). *The Assessment of Aphasia and Related Disorders.* (2nd Ed). Philadelphia: Lea and Febiger.

Helm-Estabrooks, N. & Albert, M. L. (2004). *Manual of Aphasia and Aphasia Therapy*. Austin, TX: PRO-ED, Inc.

Helm-Estabrooks, N. (1984). Severe aphasia. In A. Holland (Ed.) *Language Disorders in Adults.* San Diego: College Hill Press.

Henaff Gonon, M., Bruckert, R., & Michel, F. (1989). Lexicalization in an anomic patient. *Neuropsychologia, 27,* 391-407.

Ho, K. M., Weiss, S. J., Garrett, K., & Lloyd, L. L. (2005). The effect of remnant and pictographic books on the communicative interaction of individuals with global aphasia. *Augmentative and Alternative Communication, 21,* 218-232.

Holland, A. L., Fromm, V., & DeRuyter, F. (1996). Treatment efficacy for aphasia. *Journal of Speech and Hearing Research, 39,* S27-S36.

Horner, J., Loverso, F., & Gonzalez-Rothi, L. (1994). Models of aphasia treatment. In R. Chapey (Ed.), *Language intervention strategies in adult aphasia* (3rd ed., pp. 135-145). Baltimore, MD: Williams and Wilkins.

Horton, S. and Byng, S. (2000). Examining interaction in language therapy. *International Journal of Language and Communication Disorders, 35,* 355-376.

Howard, D., Patterson, K., Franklin, S., Orchard-Lisle, V. and Morton, J. (1985b). Treatment of word retrieval deficits in aphasia: A comparison of two methods. *Brain, 108*, 817-829.

Kertesz, A. (1982). *Western Aphasia Battery*. New York: Grune & Stratton, Inc.

Kiran, S., & Bassetto, G. (2008). Evaluating the effectiveness of semantic-based treatment for naming disorders in aphasia: What works? *Seminars in Speech and Language, 29,* 71-82.

La Pointe, L. L. (2005). Foundations: Adaptation, Accommodations, Aristos. In L. L. La Pointe (Eds). *Aphasia and Related Neurogenic Language Disorders (*pp: 1-18). New York: Thieme Medical.

Lasker, J., Hux, K., Garrett, K., Moncrief, E., & Eischeid, T. (1997). Variations on the written choice communication strategy for individuals with severe aphasia. *Augmentative and Alternative Communication, 13,* 108-116.

Longerich, M.C & Bordeaux, (1954). *Aphasia Therapeutics*. New York: The Macmillan Company.

Lyon, J. G. (1992). Communication use and participation in life for adults with aphasia in natural settings: The scope of the problem. *American Journal of Speech-Language Pathology, 1*, 7-14.

Lyon, J. G. (1995). Drawing: Its value as a communication aid for adults with aphasia. *Aphasiology, 9,* 33-49.

Lyon, J. G. (1998). Treating "the whole" of aphasia. Paper presented at the Annual Spring Rehab Conference, Lincoln, NE.

Lyon, J. G., & Helm-Estabrooks, N. (1987). Drawing: Its communicative significance for expressively restricted adults. *Topics in Language Disorders, 8,* 61-71.

McKelvey, M., Dietz, A., Hux, K., Weissling, K., & Beukelman, D. (2007). Performance of a person with chronic aphasia using a visual scene display prototype. Journal *of Medical Speech Language Pathology, 15,* 305-317.

Patterson, K.E., Purell, C. & Morton, J (1983). The facilitation of word retrieval in aphasia. In C. Code & D. Muller (Eds). *Aphasia Therapy* (pp 76-87). London: Arnold.

Pease, D., and Goodglass, H. (1978). The effects of cueing on picture naming in aphasia. *Cortex 14,* 178-189.

Poeck, K., Huber, W., & Williams, K. (1989). Outcome of intensive language treatment in aphasia. *Journal of Speech and Hearing Disorders, 54,* 471-479.

Pring, T., White-Thomson, M., Pound, C., Marshall, J. & Davis, A. (1990). Picture/word naming tasks and word retrieval: Some follow-up data and second thoughts. *Aphasiology, 4,* 479-483.

Ross, D., & Spencer, S. (1980). *Aphasia Rehabilitation-An Auditory and Verbal Task Hierarchy.* Illinois: Charles.C.Thomas.

Venogopal, M.B., & Goswami, S.P (2005). *Manual for Adult Non-fluent Aphasia Therapy-in Kannada (MANAT-Kannada). (Articles based on Dissertation done at AIISH), Vol III:* 2004-2005, 181-189, All India Institute of Speech and Hearing, Mysore, India.

GRAMMATICALITY JUDGEMENT IN ENGLISH AMONG TYPICALLY DEVELOPING PRIMARY SCHOOL CHILDREN: A PRELIMINARY INVESTIGATION

[1]Reya Ann Varghese & [2]Lakshmi Venkatesh

Abstract

The present study assessed grammaticality judgment abilities among typically developing children in English in the Indian context. Grammaticality judgment was studied using sentence acceptability and sentence correction tasks in two groups of children; one group of children studying in grade II (7-year-olds') and another group of children studying in grade V (10-year-olds'). Results revealed a developmental trend in performance of the two groups of children on the two grammaticality judgment tasks in English. Consistent with earlier findings from English speaking children, word order reversals were easier to detect in sentence acceptability task and also easier to correct relative to other errors in sentences such as morpheme deletions and wrong syntactic agreements for children in both grades. The current study provided preliminary developmental data on syntactic awareness task of grammaticality judgments in typically developing children within the Indian context. Such developmental data has may be used for developing protocols for assessing metalinguistic performance of children with language impairments and language based learning disabilities in comparison to typically developing children.

Key Words: *Syntactic awareness, metalinguistics, ESL, linguistic awareness*

Metalinguistic awareness refers to the ability to deliberately reflect upon and manipulate the structural features of spoken language, treating the language system itself as an object of thought, as opposed to using the language system to comprehend and produce sentence (Tunmer, Pratt & Herriman, 1984). It is categorized into four main categories namely phonological, word, syntactic, and pragmatic awareness. Phonological and word awareness refers to the subunits of spoken language (the phonemes and words) and involves the ability to segment words into their constituent phonemes, blending of phonemic units, segment sentences or phrases into words, separation of words from their referents. Pragmatic awareness refers to the relationships that obtain among sets of interrelated propositions and involves the ability to detect the inconsistencies between sentences, recognition of message inadequacy, and awareness of macrostructures. Finally, syntactic awareness refers to the structural representation of the linguistic meaning associated with an utterance and involves the ability to make judgment of semantic and grammatical well formedness of strings, correction of word order violations, and completion of sentences with missing words. Various syntactic awareness tasks (grammaticality judgment, correction, repetition and localization) have been used to effectively access the children's ability to manipulate their syntactic knowledge. Grammatically judgment is one of the most effective tasks used to understand the syntactic awareness skills in young children (Correa, 2004). The centrality of grammatical judgments in the linguistic theories of the 1970s was reflected in concurrent research on the acquisition of language in children. Early research on grammaticality judgment tasks in children since 1970's has documented that acquisition of grammatical judgment ability is a gradual process and is qualitatively different at different ages (e.g., Gleitman & Gleitman, 1970; Hakes, 1980; Scholl & Ryan, 1980 among others). Judgments for linguistic forms are attention demanding and it requires children, attend to and discern the language unit targeted by the metalinguistic task (Kamhi & Koenig, 1985). Although children may comprehend or produce a given utterance before the age of four years, they might not be able to make linguistic judgments about the grammaticality of these sentences until they are older (Bever, 1970).

There is considerable evidence that syntactic awareness plays a significant role in performance on reading. Syntactic processing or awareness of syntactic information relates to reading comprehension by facilitating sentence- and text-level integration and monitoring skills (Tunmer & Bowey, 1984). Syntactic awareness along with phonological awareness, and naming speed was found to be a predictor of reading and spelling performance in first graders (Plaza & Cohen, 2003). A theoretical model of reading acquisition

[1]Speech Language Pathologist, U.S.A, Email: riyann08@gmail.com & [2]Associate Professor, Dr. S. R. Chandrasekhar Institute of Speech & Hearing, Bangalore, Email: lakshmi27@gmail.com

proposed by Tunmer & Bowey, (1984) considers metalinguistic abilities as essential in the development of cognitive processes necessary to sustain rapid fluent reading. The model predicts that the each of the metalinguistic ability (phonological awareness, word awareness, syntactic awareness and pragmatic awareness) differentially contribute to variability in reading achievement as a function of stage of reading development. In the early stages, focus is primarily on the acquisition of decoding skills, phonological and word awareness skills. However, as the child progresses to advanced stage, focus shifts more towards comprehension of text, syntactic and pragmatic awareness skills. Children with good reading comprehension skills performed better on syntactic awareness tasks in comparison to children with poor reading comprehension skills (Nation & Snowling, 2000). In addition, children's performance was influenced by the syntactic complexity and semantic ambiguity of the sentences. It was noted that poor comprehenders have language processing difficulties encompassing grammatical as well as semantic weaknesses, although their phonological processing skills are normal.

Metalinguistic skills allow an individual to use language to talk about language. It is commonly agreed among second language acquisition researchers and classroom teachers that student best demonstrate their grammatical competence via production and interaction. For general language proficiency, bilingual children tend to have smaller vocabulary in each language than monolingual children in their language. However, their understanding of linguistic structure i.e, their metalinguistic awareness is at least as good as and often better than that of comparable monolinguals (Bialystok, 1988).

The acquisition of literacy skills in these children depended on the relationship between the two languages and the level of proficiency in the second language. In the case of second language reading, the learner needs to develop a sense of grammatical judgment (or of correct linguistic form and function) in the target language in order to gain access to the automaticity of interacting with text via meaning. Additionally, the learner needs to develop his or her own way of judging and interpreting textual meaning using what is more accessible to him or her. This kind of cognitive functioning requires conscious reflection on language structures (Widdowson, 1979).

The metalinguistic abilities of school going children speaking Indian languages are limited but various Indian studies reveal its importance and role in respective language development in the Indian context. Studies have investigated grammaticality judgments of Telugu speaking elementary school children (Vasanta, Sastry & Maruth, 1995), grammaticality judgment in Marathi speaking typically developing children and children with mental retardation (Bhishe, 2002). Studies have also investigated relationship between syntactic awareness and reading abilities in typically developing children speaking Oriya (Prakash & Mohanty, 1995), and Kannada (Karanth & Suchitra, 1993), as well as in adults (Karanth, Kudva & Vijayan, 1995). All the above studies involved investigations of syntactic awareness in the primary language or L1 with children attending schools having medium of instruction as their first language.

Overall, the studies found that metalinguistic ability as revealed in grammatically judgments tasks (sentence acceptability and sentence correction) improved with age or grade in which children are studying. As age increased, the children's judgment became increasingly like those of the adults. Similar to the findings among English speaking children, metalinguistic abilities were acquired gradually, strengthening as the child grows older and with increasing command over his or her language. Considerable increases in performance of children observed at around middle childhood (6 -7; 6 years or 7 - 8 years) were suggested to indicate the effect of acquisition of literacy on one's ability to master grammaticality judgment (Karanth & Suchitra, 1993; Vasanta et al., 1995). Findings by Karanth & Suchitra (1993) revealed that children below the age of six years were unable to grammaticality judgments of sentences. Beginning at ages 6-7 and with a rapid spurt at ages 7-8, children did not demonstrate ceiling performance even till the age of 11 years suggesting that children continue to became increasingly proficient in the grammaticality judgment tasks, probably attaining adult like sensitivity to grammaticality only much later into adolescence. Performance in sentence correction task on the whole was reported to be better in comparison to sentence acceptability task suggesting that it was more sensitive in getting the children to focus on the grammatical considerations as opposed to the content (Vasanta et al., 1995). There was some evidence of language specific syntactic characteristics influencing grammatically judgments. While word order reversals were reported to be easier to detect among English speaking children, children made increased accurate judgments of morpheme deletions in comparison to word order reversals in Telugu (Vasanta et al., 1995).

Need for the study: In the Indian context, a majority of children attend primary schools with English as the medium of instruction and begin literacy instruction in English, a non-dominant language rather than in the primary language spoken at home. With the increase in awareness of learning disabilities, language based learning disabilities are increasingly being identified among school going children. Often, assessment of reading and writing assessments of children at risk for literacy or academic difficulties are performed in English. Increasingly, intervention for language based learning difficulties is being sought in English language in order for the child to function successfully in the educational setting. Considering, the strong relation between syntactic awareness and reading comprehension, assessment of syntactic awareness becomes important for children with language impairments as well as language based learning difficulties. There is some evidence of role of syntactic awareness on sentence comprehension among second language learners as well. For example, sentence comprehension in second language readers (Spanish speaking learners of French), correlated strongly with syntactic awareness in addition to overall oral competence in L2 (Lefrançois & Armand, 2003).

Although several studies have investigated syntactic awareness in Indian languages among typically developing children (e.g., Vasanta et al., 1995; Karanth & Suchitra, 1993 among others), investigations of performance of typically developing children on syntactic awareness in English are lacking. There is a need to assess syntactic awareness skills in English among typically developing children who attend English medium schools and speak English in addition to their primary home language. Such studies would provide insights for assessment of syntactic awareness among children with language based learning disabilities.

Aim of the study: The current study was planned to assess grammaticality judgment of typically developing children in English. Grammaticality judgment was studied using sentence acceptability and sentence correction tasks by including two groups of children; one group of 7- year-old children studying in second grade and another group of 10-year-olds' studying in fifth grade. All children were from primarily Kannada and English speaking homes and studied in English medium schools.

Method

Participants

A total of 46 typically developing children including 23, 7-year-olds' and 23, 10 year olds' participated in the study. Children were divided into two groups based in their grade in school: children studying in grade II and children studying in grade V. Each group consisted of a total of 23 children with nearly equal number of boys and girls. Children were recruited from different schools in the city of Bangalore. All children were from primarily Kannada speaking families and reported use of English in addition to Kannada at home. Children were studying in English medium schools since preschool. Children fulfilled the following inclusionary and exclusionary criteria: i) No history of developmental delay, speech deficits, psychological or neurological problems as per parental report, ii) No oromotor problems as per an informal oral motor examination, iii) No hearing loss on the basis of informal screening and iv) Satisfactory academic performance on the basis of teachers' reports.

Table 1: *Distribution of children in grade II and grade V*

	n	Number Female/ Male	Age (years; months)		
			Mean	SD	Range
Grade II	23	13/10	7;6	0;7	7;0 - 8;6
Grade V	23	14/9	10;5	0;6	10;0 - 11;4

Language assessment

Children's receptive and expressive language skills were screened using the Assessment of Language Development (ALD; Lakkanna, Venkatesh & Bhat, 2008). ALD is an assessment tool to measure language development in Indian children from birth to 7;11 years. The assessment covers both receptive and expressive language skills and includes aspects of language such as vocabulary, syntax, semantics as well as thinking/reasoning skills. For the purposes of the current study, ALD served to ascertain typical development of language development in both groups of children. Both groups of children achieved ceiling performance on ALD indicating that the receptive and expressive language skills of children in grade II was age appropriate and those of children in grade V was at least in the range of 7;0-7;11 years. In addition to ALD, all children were administered the Test for Auditory Comprehension of Language - revised

(TACL-R; Carrow-Woolfolk, 1985). The TACL-R assesses auditory comprehension of specified lexical and grammatical forms of English forms grouped into three categories: word class and relations, grammatical morphemes and elaborated sentences. The items in TACL-R have been adapted to assess children within the Indian context by administering the test on 200 children between the age range of 3;0 to 9;11 years (Varghese, 2007). Items were modified based on the responses of children. The modified items were used for administration of TACL- R.

Task and stimuli

Grammaticality judgment tasks were constructed to assess children's ability to judge the correctness of sentences and revise ungrammatical sentences. Two tasks were included in the study.

Task – 1: Sentence acceptability and sentence correction task: The first task involved judgments of sentence acceptability as well sentence correction. A set of 40 sentences comprising of 30 deviant and 10 non- deviant were included in this task. Of the 30 deviant sentences, 10 sentences were made unacceptable on the account of word order reversal (e.g. 'ate I an orange'); ten sentences were made unacceptable by deleting the morphemes (e.g. 'the glass empty', the copula verb 'is' is deleted) and in the remaining 10 sentences there was a breakdown of agreement between the subject and verb (e.g. 'she knows what it is kept', in which the correct verb form should have been 'where'). The 10 non- deviant sentences were combined with the 30 deviant sentences to make up the final list of 40 sentences. The following instructions were given to children: "Let us play a sentence game. In this game, I'm going to read you some sentences, sometimes, I will speak correctly and at other times, I will make mistakes. Sometimes there won't be any mistakes. You are going to be my teacher today. When I say a sentence correctly, you must say "correct". If you think the sentence I said was wrong, you must tell me so and correct it for me. O.K? Shall we begin?"

Scoring: *Sentence acceptability*: In scoring the forty items in the sentence acceptability task, a score of one was given when the child judged the control (non deviant) sentences as correct or deviant sentences as incorrect. Judgment of incorrect for control sentences and correct for deviant sentences received a zero score. If the child judged a deviant sentence as incorrect, but failed to give a reason why he/she thinks it is wrong, a score of one was given.

Sentence correction: Responses were counted as correct if the child first stated that the grammatical sentence was 'wrong' and then corrected it syntactically without significantly altering meaning. Two types of corrections were possible which did not alter the meaning of the sentences:

- ***Exact correction:*** The sentences are corrected appropriately to its syntactic structure while preserving the remainder of the sentences.

For e.g. Target sentence: The girl are going to school

Child: "The girl is going to school."

- ***Correction of syntax:*** The sentences corrected are not significantly addressing the target error but forms a grammatical sentence without significantly altering its meaning.

For e.g. Target sentence: Rohit are drinks milk.

Child: "Rohit drinks his milk."

Responses were counted as incorrect when the subject judged an ungrammatical sentence to be 'right' and if they were able to judge the sentence as 'wrong' but was unable to provide a syntactic correction. A score of zero were given for each of the incorrect responses.

Task – 2: Sentence correction task: An additional task of sentence correction was included. This task was constructed with a total of 30 sentences. 10 of these involved change of word order (e.g. 'the fan she switched on'); 10 required replacement of wrong morpheme with the right one (e.g. 'there are two man standing'. The correct morpheme which should be replaced to, is morpheme irregular plural 'men') and the remaining 10 sentences required correction of syntactic agreement (e.g. 'this knife are very sharp', in which the correct copula verb should have been 'is'). The instructions for sentence correction task were similar accept that this time the children were told that whatever sentence the examiner now says, was wrong and that they must correct everything she says. ***R***esponses were counted as correct if the child corrected the incorrect sentences without significantly altering meaning.

All sentences used were between four and seven morpheme in length, and contained lexical choices that would be familiar to young elementary school-age children. The sentences were initially shown to a linguist for its grammatical correctness and were then given to teachers of grade II and III for assessing familiarity of sentences. Only sentences judged as familiar by teachers were included in the final list for the two tasks.

Procedure

All children were tested individually in relatively quiet and familiar surroundings, i.e. in their respective schools. Informed consents were taken from parents before administering the protocol. Task administration procedures were carried out in two days. On day one, all children were administered the ADL and TACL, followed by the administration of the first task involving sentence acceptability judgments and sentence correction. On day two, the second task of sentence correction was administered. Sentences were randomized within the two sets and presented to children. Instructions were provided in English. Initially, rapport was established with the child and the child was given intermittent breaks when required depending on the temperament of each child. Experimental items were preceded by practice items in which feedback was given to establish the kinds of judgments of interest. A number of practice items were given to the subjects to ensure that they were able to perform the task. No feedback was given during the experimental items. Items were repeated once if the child did not give a response and appeared to be distracted or requested repetition. All responses were recorded by using a Philips digital audio recorder using an external microphone placed around 10 cm from the child's mouth. The responses of children were scored online by the experimenter as the testing continued. In addition, where ever needed, the experimenter listened to the audio samples and confirmed the scoring for each child.

Statistical Analysis: Independent sample t-tests were used to compare the performance of children in two grades on the different sections of the sentence acceptability and sentence correction tasks.

Results and Discussion

Sentence Acceptability

The performance of children in grade II and grade V on the sentence acceptability task are described in Table 2. Independent sample t-test used to compare the overall performance of children in grade II and grade V on the sentence acceptability task found that children in grade V (M = 34.26, SD = 2.90) performed significantly higher in comparison to children in grade II [(M = 30.04, SD = 4.49); t(44) = 3. 787, p = 0.000].

Table 2*: Performance of children on sentence acceptability task*

	Grade II			Grade V			t - test (df = 44)	
Sentence Acceptability	Mean	SD	Min - Max	Mean	SD	Min - Max	t	p
Word Order Reversal	9.61	0.89	6 - 10	9.96	0.21	9 - 10	-1.822	0.075
Morpheme Deletion	7.04	1.74	2 - 10	7.04	1.69	4 - 10	0.000	1.000
Wrong Syntactic Agreement	6.83	2.29	0 - 10	8.09	1.70	4 - 10	-2.119	0.040
Non Deviant Sentences	6.57	2.57	1 - 10	9.17	0.83	8 - 10	-4.625	0.000
Total (40)	30.04	4.49	19 - 36	34.26	2.90	29 - 40	-3.787	0.000

Comparisons between the two groups of children for the different categories of sentences showed that children in the two

grades did not differ in their performance on sentences with word order reversals and morpheme deletions. Children in grade II and grade V were able to accurately identify word order reversals in sentences as incorrect. The group mean for word order reversals was 9.61 (SD = 0.89) for children in grade II and 9.96 (SD = 0.21) for children in grade V. Morpheme deletions were relatively difficult for both groups of children to identify accurately. The performance of children in grade II (M = 7.04, SD = 1.74) was not significantly different (t (44) = 0.000, p = 1.0) from the performance of children in grade V (M = 7.04, SD = 1.69) on judgments of morpheme deletion. Some examples of which morpheme deletions which were difficult for children to identify in the sentence acceptability judgment included, 'it is the elephant trunk' and 'I see plane in the sky', In these sentences, the morphological markers, possessives 's' and articles 'a', were deleted respectively.

The performance of children in the two groups differed significantly for sentences with wrong syntactic agreement and the non-deviant sentences. Children in grade V were able to identify wrong syntactic agreements with greater accuracy in comparison to children in grade II. The difference between the performance of children in grade V (M = 8.09, SD = 1.70) and grade II (M = 6.83, SD = 2.29) was statistically significant (t(44) = 2.119, p = 0.04). Some examples of sentences in which erroneous judgments were made include, 'He is washing his car that it is dirty' and 'I know what she went'. In the first sentence (conjoining sentence), 'because' was deleted to cause a wrong syntactic agreement. In the second sentence (embedded wh-question sentence) 'where', was deleted to cause a wrong syntactic agreement. Similarly, there was a statistically significant difference in the performance of children in grade V (M = 9.17, SD = 0.83) and grade II (M = 6.57, 2. 57) on accurate judgments of non deviant sentences (t(44) = 4.625, p = 0.000). Children in grade V were able to identify non-deviant sentences as correct. However, children in grade II tended to identify non-deviant sentences as incorrect and attempted to correct the sentences by changing the syntax of the sentences. For example, sentences such as 'He pointed at the door' and 'The girl is walking to school' were identified as incorrect and children corrected the sentences as 'He is pointing at the door' and 'The girl is going to school' respectively. This finding of poor performance on non-deviant sentences in comparison to some deviant sentences (word-order reversal and morpheme deletion) among the younger children is in contrast to earlier findings of sentence acceptability in Kannada and Telugu (Karanth & Suchitra, 1993; Vasanta, et.al., 1995). Children consistently performed better on non-deviant sentences in comparison to deviant sentences in Kannada and Telugu. Poor performance of younger children on the non-deviant sentences suggests that 7-year-old children are continuing to master the morphosyntactic characteristics of English.

Overall, the results of sentence acceptability task showed that children in grade II were able to make accurate judgments of incorrect sentences; their performance on judgments of wrong syntactic agreement and the non-deviant sentences was significantly lower in comparison to children in grade V. The total scores obtained by children in grade II ranged from 19 -36. The findings of the current study in terms of the ability of 7-year-old's to perform acceptability judgments is in consonance with findings from several studies (e.g., Hakes, 1980; Vasanta *et al*., 1995; Karanth & Suchitra, 1993; Bhishe, 2002). These studies included children in younger age groups as well and found that performance of children on sentence acceptability typically showed a spurt in performance around the age of 7 years (Vasanta, et al, 1995; Karanth, Kudva & Vijayan, 1995; Karanth & Suchitra, 1993) consistent with increased demands on literacy performance in formal school. Performance of children continued to improve with age and did not reach adult like even till the age of 11 years (Karanth, Kudva & Vijayan, 1995). Similar results were obtained in the current study.

Word order reversals were easier to judge relative to judgment of other errors in sentences such as morpheme deletions and wrong syntactic agreements for children in both grades. In fact, word order reversals were even easier to judge in comparison to non-deviant sentences by children in grade II. This finding is in agreement with the findings of Hakes (1980) who reported that children performed better on the word order condition, reflecting the fact that word order changes lead to more gross violations than other changes and therefore are easier to detect. Hakes and colleagues further suggested that around the age 7 or 8, a linguistic criterion is added and children reject a sentence based on the linguistic form rather than content. Similar findings were reported by Wulfeck, (1993) in terms of significantly lower response time to word order condition task, in comparison to the other syntactic acceptability tasks. Children could spontaneously detect the inappropriate reversals of the sentence structures given. English being a strong word order language with a weak inflectional morphology system resulted in children noticing violations of word order more easily. Overall, word order was a powerful cue that develops early compared to rules of agreement or morphology, which are mastered slowly.

The findings of the current study differed from those of Vasanta et al., (1989) on sentence acceptability in Telugu speaking children. Children performed poorer on word order violations in comparisons to other deviations in sentences such as morpheme deletion and syntactic agreement. Differences in language structures explain the differences in results. The inflectional morphology permits a wide variation in word order in Telugu when compared to that of English making violations in word order difficult to detect in Telugu. Therefore the role of word order in determining grammatical well-formedness of sentence is language specific.

Sentence Correction Tasks

Two sets of sentence correction tasks were administered. The first set of sentence correction task followed the sentence acceptability judgments in that children were also asked to correct sentences identified by them as incorrect.

Another set of sentence correction task was performed separately with different sets of morpheme deletions and incorrect syntactic agreements.

Sentence Correction Task – 1

The sentence correction task- 1 followed the sentence acceptability task. Children corrected the sentences which were identified as deviant by them. The 10 non deviant sentences were not taken into account for correction. Although the task included a total of 10 deviant sentences each for word order, morpheme deletions and syntactic agreement, the number of opportunity for corrections in this task were dependent on the number of sentences which were accurately identified as deviant by children in the acceptability task. For example, word order reversals were found to be accurately judged as deviant by children in both groups as seen the results of the sentence acceptability task. Hence children had more number of opportunities to correct sentences with word order reversals. Table 3 presents the results of sentence corrections made on sentences judged as deviant in the sentence acceptability task.

Table 3: *Sentence corrections scores for sentences judged as deviant in the sentence acceptability task*

	Grade II			Grade V			t - test (df = 44)	
Sentence Correction – I	Mean	SD	Min - Max	Mean	SD	Min - Max	t	p
Word Order Correction	9.09	1.08	6 - 10	9.83	0.39	9 - 10	-3.081	0.004
Morpheme Correction	4.83	2.01	1 - 8	6.70	1.69	4 - 10	-3.409	0.001
Correct Syntactic Agreement	3.74	1.98	0 - 8	7.26	2.24	2 - 10	-5.646	0.000
Total (30)	17.65	3.64	10- 25	23.78	3.48	17 - 30	-5.842	0.000

Independent sample t-test used to compare the overall performance of children in grade II and grade V on the sentence corrections found that children in grade V (M = 23.78, SD = 3.48) performed significantly higher (t (44) = 5.842, p = 0.000) in comparison to children in grade II (M = 17.65, SD = 3.64). Comparisons between the two groups of children for the different categories of sentences showed that children in the two grades differed in their performance on sentences involving word order corrections; morpheme correction and correction of syntactic agreement.

Children in grade II and grade V were able to accurately identify word order reversals in sentences as incorrect. The group mean for word order reversals was 9.09 (SD = 1.08) for children in grade II and 9.83 (SD = 0.39) for children in grade V. As seen from table 4.2, there was increased variability in the performance of children in grade II in comparison to children in grade V. This resulted in significant difference in the performance of children in both groups (t (44) =3.081, p= 0.004); children in grade V performed higher in comparison to children in grade II.

Morpheme corrections and corrections of syntactic agreement were relatively difficult for both groups of children to perform. For morpheme corrections, performance of children in grade II (M = 4.83, SD = 2.01) was significantly lower in comparison to the performance of children in grade V (M = 6.70, SD = 1.69). Children in grade V were able to correct syntactic agreements with greater accuracy in comparison to children in grade II. The difference between the performance of children in grade V (M = 7.26, SD = 2.24) and grade II (M =3.74, SD = 1.98) was statistically significant (t (44) = 5.646, p = 0.000). Some examples of sentences which were difficult for children include: ‘He is eating chappati or he is hungry’ and ‘I know where is hiding’; the conjoining sentence element ‘because’ and embedded wh-question ‘who’, were replaced by incorrect forms in the above sentences respectively and children were required to correct them by including them in the sentences. Children in grade V were accurate in making corrections for the incorrect syntactic agreement compared to children in grade II.

Sentence Correction Task- 2

The sentence correction task- 2 involved a new set of 30 sentences. Of which 10 deviant sentences were used for word order correction task, 10 deviant sentences for morpheme correction task and 10 deviant sentences for correct syntactic agreement tasks. The sets of morpheme deletions and incorrect syntactic agreement differed from those used in the task-1. In this task the children were asked to correct all the sentences presented. Table 4 shows the results of the second sentence correction task.

Table 4*: Performance of children in sentence correction task*

	Grade II			Grade V			t - test (df = 44)	
Sentence Correction – II	Mean	SD	Min - Max	Mean	SD	Min - Max	t	p
Word Order Correction	9.30	0.82	7 - 10	9.83	0.49	8 - 10	-2.613	0.012
Morpheme Correction	3.91	1.65	1 - 7	7.00	1.54	4 - 9	-6.567	0.000
Correct Syntactic Agreement	4.52	1.78	2 - 8	8.43	1.44	6 - 10	-8.194	0.000
Total (30)	17.74	2.67	13 - 22	25.26	3.09	19 - 29	-8.834	0.000

Independent sample t-test used to compare the overall performance of children in grade II and grade V on the sentence correction task found that children in grade V (M = 25.26, SD = 3.09) performed significantly higher in comparison to children in grade II (M = 17.76, SD = 2.67). Children in grade II and grade V were able to accurately correct word order reversals in sentences. The group mean for word order reversals was 9.30 (SD = 0.82) for children in grade II and 9.83 (SD = 0.49) for children in grade V. The performance of children in grade II (M = 3.91, SD = 1.65) was significantly lower (t (44) = 6.57, p = 0.000) in comparison to the performance of children in grade V (M = 7.00, SD = 1.54). Examples of morpheme correction which were difficult for children to perform in the sentence correction task: 'There are five sheeps' and 'The girl buying a dress', here the morphological markers, irregular plurals 'sheep' and auxiliary 'is', were deleted respectively. This difficulty was seen greater for children in grade II compared to children in grade V. It was also noted that the grade V children attempted to correct the sentences by changing the syntax of the sentences.

The performance of children in the two groups differed significantly for sentences which required correct syntactic agreement. Children in grade V were able to correct syntactic agreements with greater accuracy in comparison to children in grade II. The difference between the performance of children in grade V (M = 8.43, SD = 1.44) and grade II (M = 4.52, SD = 1.78) was statistically significant. Some examples include 'It rain heavily yesterday' (regular past tense'ed' is deleted); 'This flower was beautiful' (copula verb 'is' is replaces with was). Children in grade V showed more instances of accurate corrections of sentences involving such in correct syntactic agreements, in comparison to children in grade II.

Analysis of the types of correction made by children revealed the corrections used by children in grade II involved the use of 'exact corrections'. However, children in grade V attempted correct the sentences by changing the syntax (without altering the meaning). Analysis of incorrect attempts at correction showed that children's incorrect responses includes, exact repetition of the target sentence, corrections focused on the syntactic error but did not result in grammatically correct sentence and occasional semantic modifications. Children in grade II tended to repeat the target sentence more often. Both tasks of sentence correction revealed a similar pattern of results across grades as well as across the sentence types, validating the results further. No attempts were made at comparing the two tasks as both tasks included different sets of morpheme deletions and incorrect syntactic agreements.

Overall the results of the sentence correction task revealed that performance on correction task improved with age, with children in grade V performing significantly higher in comparison to children in grade II in all the categories of sentence correction. Findings are consistent with several other studies which have reported that performance in sentence correction tasks increased with age (e.g., Pratt, Tunmer & Bowey, 1984; Vasanta, et al, 1995; Bhishe, 2002). Similar to the finding in the sentence acceptability task, comparisons of types of sentences in the sentence correction tasks indicated that word order reversals were easier to correct relative to other errors in sentences such as morpheme deletions and wrong syntactic agreements for children. Such differences are more apparent for younger children in grade II. The gross violations caused by word order reversals were easier to correct by children in both grades. In contrast correction of morpheme deletions and syntactic agreements required mastery of grammatical morphemes and other complex grammatical forms to mark finer changes in the sentence structures. This may have posed limitations on the ability of younger children to correct morpheme deletions and more complex incorrect syntactic agreements in sentences.

Indeed, the sentence correction task was more challenging in comparison to the sentence acceptability task. Children received lower scores on sentence correction task in comparison to sentence acceptability task. Sentence correction task requires the subject to hold the sentence in the working memory, articulate the response and in this process makes it more taxing than the acceptability judgment task. Similar results were obtained by Bhishe (2002) in a study of grammaticality judgment in typically developing children speaking Marathi and children with mental retardation. Tsang & Stokes (2001) also reported higher scores on sentence acceptability in comparison to sentence correction in a study of Cantonese children.

The sentence correction task revealed differences between the groups which were not apparent in the sentence acceptability task. For example, although both groups did not differ in terms of accurate judgments of morpheme deletions in the sentence acceptability task, significant differences were seen in terms of morpheme corrections. Indeed there are suggestions that grammatical awareness may be better evaluated using sentence correction tasks than sentence acceptability tasks, because in the former, the children's attention is drawn to grammatical considerations relative to the latter in which children may be attending to the content of the sentence than its form (Pratt et al.,1984).

Performance on TACL-R

The raw scores obtained by children on the different subsections in TACL-R are shown in Table 5. Independent sample t-test used to compare the overall performance of children in grade II and grade V on TACL found that children in grade V (M = 106.35, SD = 4.96) performed significantly higher in comparison to children in grade II (M = 95.96, SD = 5.02). Comparisons between the two groups of children for the different categories of TACL showed that children in the two grades significantly differed in their performance on all the three categories. Performance increased with grade. Children in grade V (M = 39.09, SD = 0.60) scored significantly higher than children in grade II (M = 37.43, SD = 1.38) on word class and relations. Similar results were seen for grammatical morphemes. The performance of children in grade V (M = 34.13, SD = 2.74) was significantly higher than those of children in grade II (M = 29.74, SD = 2.18) on the grammatical morpheme section. Children in grade V (M = 33.09, SD = 2.17) also scored significantly higher in the elaborated sentence section in comparison to children in grade II (M = 28.78, SD = 2.15).

Table 5: *Raw scores obtained by children on TACL-R*

	Grade II			Grade V			t – test (df = 44)	
TACL - Sections	Mean	SD	Min - Max	Mean	SD	Min - Max	t	p
Word Class and Relations (40)	37.43	1.38	33 -39	39.09	0.60	38 - 40	-5.284	.000
Grammatical Morphemes (40)	29.74	2.18	26 - 33	34.13	2.74	30 - 39	-6.022	.000
Elaborated Sentences (40)	28.78	2.15	23 - 31	33.09	2.17	29 - 37	-6.750	.000
TACL - Total (120)	95.96	5.02	83 - 103	106.35	4.96	100 - 115	-7.060	.000

In terms of task complexity or differences among sections, comprehension of word class and relations were the easiest followed by grammatical morphemes and elaborated sentences for both groups of children. These results support the findings of higher performance of children on sentences with word order reversals in comparison to those with morpheme deletions and incorrect syntactic agreement sentences in both sentence acceptability and sentence correction tasks.

Conclusions

The current study provided preliminary developmental data on syntactic awareness tasks of grammaticality judgments in English among typically developing children within the Indian context. Such developmental data may be used for further development of assessment protocols for assessment of children with language impairments and language based learning disabilities or poor academic performance in comparison to typically developing children. Instruction material or activities based on the syntactic awareness tasks used in the current study may be developed for use in schools or homes to improve syntactic awareness skills in children with language impairments as well as those with language based learning difficulties.

Limitations and future directions: Sample size used for the study was small suggesting caution in generalizing the findings. The current study only included children as young as 7-year-old's studying in second grade in line with earlier findings of emergence of grammaticality judgment abilities coinciding with formal literacy instruction (e.g., Karanth & Suchitra, 1993). However, future studies may be directed at understanding the development of grammatically judgment by sampling participants in continuous age intervals across a wide age group. Gender contingent variations if any, may also be explored by including a larger sample of participants. Comparisons between the different categories of morphemes and syntactic agreement used for construction of deviant sentences were not made due to limited number of sentences in each category. The study did not measure reading comprehension skills which are closely related to syntactic awareness skills. Future studies may address the relationship between syntactic awareness and reading comprehension in typically developing children as well as those with language based learning difficulties. Performance of children on other syntactic awareness such as analogy and replication tasks may also be studied in order to effectively assess children's intentional manipulation of their syntactic knowledge.

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References

Bever, T. G. (1970). The cognitive basis for linguistic structures. In J. R. Hayes (Ed.). *Cognition and the development of language* (pp. 297-362). New York: Wiley.

Bhishe, A. (2002). Grammaticality judgment in Marathi speaking school going normal and mental retardation children. Unpublished Masters Dissertation, University of Mumbai, Mumbai.

Bialystok, E. (1988). Levels of bilingualism and levels of linguistic awareness. *Developmental Psychology, 24* (4), 27-44.

Carrow-Woolfolk, E. (1985). Test for Auditory Comprehension of Language – Revised Edition. DLM Teaching Resources, Texas, USA.

Correa, J. (2004). The evaluation of children's syntactic awareness: A methodological analysis. *Psicologia: Teoria e Pesquisa [online], 20* (1), 69-75.

Gleitman, L. R., & Gleitman, H. (1970). Phrase and paraphrase: Some innovative uses of language. New York: Morton.

Hakes, D. T. (1980). The development of metalinguistic abilities in children. Berlin: Springer-Verlag.

Kamhi, A.G., & Koeing, L.A. (1985). Metalinguistic awareness in normal and language disordered children. *Language, Speech and Hearing Services in School,* 16, 199-210.

Karanth, P., & Suchitra, M.G. (1993). Literacy acquisition and grammaticality judgments in children. In R. Scholes (Ed.), Literacy and Language Awareness (pp.143-156). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Karanth, P., Kudva, A., & Vijayan, A. (1995). Literacy and linguistic awareness. In B. de Gelder & J. Morais (Eds.), Speech and reading: A comparative approach. Oxford: Taylor & Francis.

Lakkanna, S., Venkatesh, K., & Bhat, J. S. (2008). Assessment of Language Development. Omni Therapy Services. USA: CA.

Lefrancois, P., & Armand F. (2003). The role of phonological and syntactic awareness in second – language reading: The case of Spanish-speaking learners of French. *Reading and Writing, 16* (3), 219-246.

Nation, K., & Snowling, M. K. (2000). Factors influencing syntactic awareness skills in normal readers and poor comprehenders. *Applied Psycholinguistics*, *21*(2), 229-241.

Plaza, M., & Cohen, H. (2003). The interaction between phonological processing, syntactic awareness, and naming speed in the reading and spelling performance of first-grade children. *Brain and Cognition, 53* (2), 287-292.

Prakash, P., & Mohanty, A. K. (1995). Development of reading, metalingusitics awareness and cognitive processing skills of Oriya children In B. Lakshmi Bai and D. Vasanta (Eds.) *Language development and language disorders: Perspectives from Indian languages* (pp 121-146). Centre for Advanced Study in Linguistics, Osmania University and Bahri publications, New Delhi

Pratt, C., Tunmer, W.E., & Bowey, J. (1984). Children's capacity to correct grammatical violation in syntax. *Journal of Child Language, 11*,129-141.

Scholl, D. M., & Ryan, E.B. (1980). Development of metalinguistic performance in early school years. *Language and Speech*, *23*, 199-211.

Tsang, K. K-S., & Stokes, S.F. (2001). Syntactic awareness of Cantonese- speaking children. *Journal of Child Language, 28* (3), 703-739.

Tunmer, W. E., & Bowey, J. A. (1984). Metalinguistic awareness and reading acquisition. In W.E. Tunmer, C. Pratt, & M. L. Herriman (Eds.), *Metalinguistic awareness in children: Theory, research and implications* (pp.144-168). New York: Springer-Verlag

Tunmer,W. E., Pratt, C., & Herriman, M. L. (1984). Metalinguistic awareness in children: theory, Research and Implications. Berling: Springer-Verlag.

Varghese, M.B. (2007). Adaptation of TACL-R on Indian population. Unpublished Master's Dissertation. University of Bangalore, Bangalore.

Vasanta, D., Sastry, J. V., & Maruth, P. R. (1995). Grammaticality judgments of Telugu speaking elementary school children. In B. Lakshmi Bai, and D. Vasanta, (Eds.) *Language Development and Language Disorders: Perspectives from Indian Languages* (147- 162). Centre for Advanced Study in Linguistics, Osmania University and Bahri publications, New Delhi

Widdowson, H. (1979). The process and purpose of reading. In H.Widdowson (Ed.) Explorations in Applied Linguistics, (pp: 171-183). New York: O. U. P.

Wulfeck, B. B. (1993). A reaction time study of grammaticality judgments in children. *Journal of Speech and Hearing Research, 36*, 1208-1215.

IS NONWORD REPETITION A TRUE CLINICAL MARKER OF SLI?

[1]Kuppuraj. S & [2] Prema. K. S.

Abstract

Background: Specific Language Impairment (SLI) is a developmental condition where despite typical general intellectual abilities language learning is effortful for a child. Children with SLI show substantial difficulty repeating nonsense words such as "frescovent" compared to children with Normal Language (CNL) skills. Poor Non Word Repetition (NWR) has been reported as a significant clinical marker of SLI. However, few studies have reported contradictory results.

Aims and Method: The present study aimed at establishing norms as well as identifying the feature among NWR performance that could serve as a clinical marker of SLI. 100 Children ages ranging from 7-13 years were taken and divided into two groups, each group comprising of 50 children for statistical convenience (7-10 yrs and 10-13yrs). Norms were developed for NWR performance at these age range and performance of SLI children (6 children in 7-13 years age range). CNL and SLI were analyzed for percentage on syllables repeated correctly, percentage of vowels and consonants correct, regularizations, reversals, additions, repetitions, substitutions, omission errors and quality of errors.
Results and Discussion: Mean and SD scores for the NWR task for the age group 7-10 and 11-13 yrs were computed. There was a reduction in percentage correct phonemes as an effect of nonword length increment. The results are discussed with reference to decrement in scores for NWR with increase in syllable length that was noted in typically developing children. Discussion extended to cognitive linguistic nature of NWR as clinical marker of SLI.

Key words*: Non word, Specific Language Impairment*

Specific Language Impairment (SLI) is a developmental condition in which a child fails to develop language like a typical child despite normal general intellectual abilities, adequate exposure to language, and in the absence of hearing impairment (Leonard, 1998). Children with SLI manifest linguistic deficits such as phonological, morphological and syntactic errors along with processing deficits (Vasanthi & Prema, 2001). Labeling children with SLI is seldom by strict diagnostic test rather by identifying linguistic or processing markers those are typical of them. Processing markers, particularly using tasks such as the Non-word repetition (NWR) appear to have the potential for indicating SLI risk as NWR task taps both processing as well as expressive dimension because the child has to perceive, store and retrieve (processing domain) the non-word before repeating it (expressive domain) (Prema, Prasitha, Savitha, Purushothaman, Chitra, & Balaji, 2010). Further study that correlated NWR accuracy with receptive and expressive language by Edwards and Lahey (1998) found strong correlation between non-word repetition accuracy and expressive language concluded that the problem lay with the nature of phonological representations in working memory and not with the ability to hold information in phonological working memory. Recent evidences have genotyped PSTM to chromosome 16q which is a quantitative trait locus for NWR (SLI Consortium, 2004).

Poor Non Word Repetition (NWR) has been reported as a significant clinical marker of SLI. Children with SLI perform poorly on repeating non words such as "frescovent" compared to typically developing children (Bishop, North, & Donlan1996; Edwards & Lahey, 1998; Ellis Weismer, Tombli, Zhang, Buckwalter, Chynoweth, & Jones 2000; Gathercole & Baddeley, 1990; Montgomery, 1995b). A nonword consists of a stimulus within the structural rules of a natural language, i.e., it can be read, written and repeated but has no conceptual meaning or semantic value in the current lexicon of that language (Santos & Bueno, 2003). Therefore, NWR task is argued to be a relatively pure measure of phonological short-term memory (PSTM) (Gathercole and Baddeley 1989). PSTM aids in storing verbal input temporarily, allows other cognitive tasks such as verbal comprehension, transfers phonological information such as word form representations to long-term memory (Montgomery, 2003). Dollaghan and Campbell (1998) stated as result of their study that NWR task differentiates children with SLI and typically developing children (NL) with high degree of

[1]Junior Research Fellow, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: kuppu_k7@ yahoo.co.in & [2]Professor in Language Pathology, AIISH, Mysore-06, Email: prema_rao@yahoo.com

accuracy. Ellis Weismer, Tomblin, Zhang, Buckwalter, Chynoweth, & Jones (2000) reported that children with language impairment as well as children who underwent language intervention performed poorly on NWR task. Authors of the study also considered NWR task as culturally unbiased task of language processing which provides useful index to indicate language disorder. Predictive ability of SLI using NWR was evaluated by Conti-Ramsden and Hesketh, (2003) using Children's Test of Nonword Repetition (CNRep by Gathercole & Baddeley, 1996) and it was found to be 81.3%, second only to past tense marker. The study identified that children who were at risk of SLI fell in lower quarter of normal distribution in NWR (performance lower than 25th centile).

Error type analysis of NWR responses of SLI children yielded prototype findings those differentiate children with SLI from children with NL. Edwards and Lahey, (1998), Marton and Schwartz, (2003), and Montgomery, (1995) reported on types of errors in NWR task among school aged SLI and control children. Phoneme substitution was more frequent than phoneme omissions for both groups, and addition of phoneme was infrequent feature. The SLI groups produced significantly more phoneme omission than the controls. The error analysis results showed that even though the frequencies of errors between the SLI and non-SLI groups differed, the error pattern was similar across two groups. Typically developing children and children with SLI did not show difference in number of syllables in repetition on studies that examined prosodic contours of non-words repetitions (Dollaghan, Biber, & Campbell, 1995, Edwards & Lahey, 1998, Roy & Chiat, 2004, Sahlén, Reuterskiöld-Wagner, Nettelbladt & Radeborg, 1999).

Santos, Bueno, and Gathercole, (2006) used The Brazilian Children's Test of Pseudoword Repetition (BCPR), a Portuguese language version of the CNRep (Gathercole & Baddeley, 1996) since word patterns in Portuguese differ from those in the English language in terms of stress and the number of syllables. Authors of the study found substitution as a dominant error type and substitutions observed more at the end of the stimuli, after the stress. They also reported of more errors in lengthy words compared to short words. In other words, the BCPR error analysis reveals that although school learning increases the efficiency of phonological loop system, its capacity is relatively constant during development.

Length of the nonword is a major factor that can influence the responses of children with NL and SLI in a NWR task. Scheer-Cohen and Evans, (in press) conducted an extensive study which included 77 children with SLI and 130 children with NL age ranging from 5-15 years to compare the error types of SLI with NL. Study used varying syllable lengths from 1-4 and revealed that children with SLI produced significantly more frequency of phoneme, consonant and vowel errors compared to children with NL at all ages with except of children below 7 years. Archibald & Gathercole, (2006b) conducted a study including children with SLI and controls from age range of 7-11 yrs, and reported that the children with SLI repeated the lengthier nonwords containing consonant clusters significantly less accurately than the control groups. They concluded the study by attributing the less accurate performance to compromised ability in verbal short-term memory, lexical knowledge, and output processes of children with SLI.

Differentiation of characteristics of children with SLI with NL group is not the sole purpose served by NWR tasks. Literature also demonstrates that detail error analysis of NWR performance expands its dicriminability between developmental disorders, such as those manifested as a result of similar cognitive underperformance. Bree, Rispens, and Gerrits, (2007) investigated whether poor NWR underlies SLI and children at risk for dyslexia. The results showed that children with SLI and the (at-risk of) dyslexia groups performed more poorly than the control group children. Preschool SLI children scored significantly below the mean of the preschool control group, indicating that poor non-word repetition performance is a clinical marker of SLI. The study also showed that almost half of the at-risk group was poor performers, which was expected on the basis of the familial risk factor of the at-risk group. The results showed that a NWR deficit early in life proven substantially for both dyslexia and SLI.

Evidence from error analysis of children with SLI revealed that children with SLI tend to retain the number of syllables in the nonword repetition task. However, they are prone to interchange the syllables or distort them, which are explained using the theory of "segment -to-frame association" (Biran & Friedmann, 2004; Levelt, 1992). The metrical frame includes the number of syllables and stress pattern of the word, and the segment portion consists of information on phonemes (consonants, vowels and clusters). Marton & Schwartz, (2003) found from their study of NWR performance of SLI that 80%

errors produced by children with SLI are segmental errors such as consonant and vowel substitution with no word structure change. According to this theory of phonological encoding in word retrieval, the segments and the structural frame of a word are processed separately. Study by Levelt, Roelofs, and Meyer, (1999) also supports that the segmental and metrical information are represented separately and accessed in parallel, thus leading to segmental errors predominantly.

Studies that address NWR as a clinical marker of SLI predominantly come from English. Though, studies conducted in Spanish and Swedish yielded support to poor NWR as clinical marker, the question of difficulties with prosodic structures which could underpin problems with NWR was raised. The Cantonese yielded contradictory results compared to English. Stokes, Wong, Fletcher, & Leonard (2006) as their result of study in Cantonese language reported that children with SLI did not score poorer that children with NL on NWR tasks. They found that although NWR is a sensitive test in Cantonese with older children scoring higher than the younger children, there is no significant difference in performance between children with SLI and their typically developing age-matched (TDAM) peers.

Prema, Prasitha, Savitha, Purushothaman, Chitra, & Balaji (2010) studied the relevance of NWR for screening children with SLI who are native speakers of Kannada language (Dravidian language spoken in Karnataka, India). Comparative design was employed for the study and the participants were matched pairs of SLI and NL children. A 14 year old Kannada speaking adolescent diagnosed as SLI who was matched for age, gender, language and socio economic status with normal child was selected. He was given fifteen non-words from a set of non-words (Prema, 1998) and performance was transcribed verbatim. The authors analyzed the transcribed samples for accuracy of response and the nature of incorrect responses. The results suggested that there was 93.3% accuracy in the repetition of non words by typically developing child compared to 46.6% for the participant with SLI. The error analysis included the analysis of the phonological processes and an examination of the productive error patterns in the children's responses. Error patterns such as additions, devoicing, omission, and liquid gliding were observed consistently in the non-word repetition of the SLI participant. One significant observation reported by the author was that, all the non-words that had liquids were incorrectly produced. Moreover backing a phonological process that is generally not observed in normal children was also predominant.

Shylaja (2010) compared 3-7 year old children with SLI and typically developing children on NWR task and found that children with SLI performed significantly poorer than NL group. Her study also revealed no relation between NWR performance and vocabulary knowledge. Substitution errors were predominant in error analysis of NWR utterances followed by deletion and addition errors. Studies from Kannada reveal that children with SLI produced significantly more errors that children with NL. They have also highlighted of unusual phonological processing in children with SLI. Shylaja, Amulya and Swapna, (In press) studied 8-12 year old children on 2-5 syllable nonword performance. They compared NWR performance of 15 children specific learning disability (SLD) with children with NL. They reported that SLD children found 4 and 5 syllable length to be difficult, where as children with NL found only 5 syllables difficult to repeat. It was found that the children with SLD had significantly higher percentage of vowel and consonant errors specifically syllable substitution and omissions compared to the children with NL. To summarize, types of errors in NWR performance of children with SLI in Kannada were closer to those described for children who are native speakers of English with substitution errors dominating deletion and addition errors.

Need and specific aims of the study

Studies from both English and Kannada show the significance of having NWR task as a tool in diagnostic battery of SLI syndrome. All the studies enunciating the significance of NWR as clinical marker of SLI used syllable lengths not exceeding 5. The need exist to enquire the significance of lengthier nonwords (until 8 syllable non-words) as clinical marker of SLI. The importance of having a standardized NWR tool in diagnosing SLI adolescents has been overlooked. So the present study aims to standardize the 2-8 syllable nonwords in Kannada. Swapna and Shylaja, (In press) standardized a 2-5 syllable length nonwords for 3-7 years population. Moreover, the significance of NWR as a clinical marker of children with SLI in adolescents is yet to be studied. A qualitative analysis of errors is needed to comment on specific types of error pattern exhibited by children with SLI. So the present study aims to

1. *Develop* mean scores for NWR task of 2-8 syllable length from age 7-13 yrs and report the performance as function of error types.

2. Investigate whether the frequency or type of errors that differentiate children with SLI from typically developing children (NL).
3. Qualitatively analysis of features of children with SLI on NWR task.

Method

The study had 98 typically developing children along with 6 children with SLI. Children for normal group were selected from 5 different schools across Mysore city. 50 participants age ranged from 7 to 10 years (group I) and 48 participant's age ranged from 11-13 years (group II) were randomly selected for the study. The participants in this group did not show any sensory, motor or cognitive deficits as per reports from class teachers. 6 children (ranging from 7-13 years) who were diagnosed as having specific language impairment using Leonard's exclusion criteria at the All India institute on Speech and Hearing, Mysore were also selected for the study. Material: Non words ranging from 2-8 syllable length were selected as stimulus. Each syllable length consisted of 5 nonwords in it, forming a total of 35 nonwords. Non words were developed and by qualified speech language pathologists who were native speakers of Kannada considering the phonotactic rules of Kannada. Participants were given the stimulus through snug ear plugs using a laptop at around 70dBSPL in a silent environment. Responses were recorded using Olympus digital recorder WS-100 and analyzed.

Analysis of data: Recorded data were analyzed for

1. Percentage of correct responses – percentage of nonwords repeated precisely (number of nonword repeated precisely divided by 5 X 100)
2. Percentage of syllables correct – number of syllables repeated correctly divided by total number of syllables/100 (for e.g. the total number of syllable for 2 syllable nonwords is 10)
3. Percentages of consonants correct- number of consonants produce correctly divided by total number of consonants in a syllable length multiplied by hundred (E.g. Number of consonants produced correctly/25 for 5 syllable nonwords length X 100)
4. Percentage of vowels correct- number of vowels produce correctly divided by total number of vowels in a syllable length multiplied by hundred (E.g. Number of vowels produced correctly/30 for 6 syllable nonwords length X 100)
5. Accuracy of responses (it was rated in 5 point rating scale, 1 being least accurate and 5 being very accurate) .

Results and discussion

I. Objective 1: Standard scores for typically developing children on NWR task

Standard scores were developed for three measures of nonword repetition analysis. The data included percentage of syllable correct (SC %), percentage of accuracy of response (AOR %), percentage of correct responses (CR %), percentage of consonant correct (% CC) and percentage of vowel correct (%VC). Mixed Analysis of Variants (ANOVA) was done to calculate mean and SD scores for % SC, % AOR and % CR for the two groups (Group I: 7-10 years and Group II: 11-13years) across syllable lengths. Repeated measures of ANOVA were done to identify whether the reduction in score as the function of increase in syllable length is significant for each measure.

I. a. Percentage of Syllables correct (% SC)

Table 1. Mean and SD for percentage of syllables correct for two age groups.

7-10 years			11-13 years		
SC (%)	Mean	SD	SC (%)	Mean	SD
2	99.01	3.60	2	98.72	4.48
3	97.70	5.30	3	98.57	3.63
4	92.88	7.96	4	99.25	2.32
5	84.84	12.77	5	95.93	3.46
6	83.58	10.14	6	91.08	9.25
7	68.66	14.21	7	78.29	14.25
8	56.76	17.41	8	69.74	15.35

Table 1, shows the reducing pattern in the value from 2-8 syllables, the mean for 2 syllables are 99 % and for 8 syllables being 56 % for group I. The man value for 2 syllables is 98 and for 8 syllables are 69 for group II. The reducing in mean as the function of increasing syllable length pattern is uniform for both the age groups. The SD values for both the groups are narrowest for 2 syllable nonwords and the broadest for 8 syllable nonwords suggesting the increasing variability in accuracy as syllable length increase. Both the age groups conformed to this pattern.

Repeated measures of ANOVA were done to see whether the reducing pattern in mean is significant between syllable lengths. The results of repeated measures of ANOVA for 7-10 years age group revealed that there is no significant difference between 2 and 3 syllable nonwords on this percentage of syllable correct. Likewise performance on 5 syllable nonwords was no significantly better than 6 syllable nonwords (See Table 3 for significance values).

The results of repeated measures of ANOVA for 11-13 years age group revealed that there was no significant difference between syllable lengths 2, 3, and 4 on percentage of syllable correct responses. However the rest of syllable nonwords were significantly different from each other, 8 syllable nonwords being the lowest (See Table 3 for significance values).

I. b. Percentage of Accuracy of response (%AOR) and Percentage of correct responses (%CR)

Accuracy of response values in Table II shows that mean value reducing from 2-8 syllables for both the age groups. The SD values are narrow for 2 syllable nonwords and the broadest for 8 syllable nonwords suggesting the increasing variability in accuracy as syllable length increases. Both the age group conformed to this pattern.

Repeated measures of ANOVA revealed no significant difference between 2 -3 and 5-6 syllable lengths on AOR in group I (7-10yrs). 4 syllable nonwords were significantly poorer than 3 and better than 5. Likewise 6, 7, and 8 syllable nonwords showed significantly poor performance compared to smaller length nonwords, 8 syllable being least accurate (See Table 3 for significance values).

Repeated measures of ANOVA in group II (11-13yrs) show that no significant difference between 2, 3, and 4 syllable length nonwords. Likewise 5 and 6 syllable nonwords also do not show significant difference among them. Accuracy of response of 8 syllable length was significantly poorer than 7 syllable nonwords. However the decreasing accuracy value was observed (See Table 3 for significance values).

Table 2: *Mean and Standard Deviation (SD) values for Percentage of accuracy of response (% AOR) and percentage of correct response (% CR) for two age groups.*

7-10 years						11-13 years					
AOR (%)	Mean	SD	CR (%)	Mean	SD	AOR	Mean	SD	CR (%)	Mean	SD
2	99.13	3.60	2	96.4	14.80	2	99.6	1.40	2	99.1	4.08
3	98.50	3.91	3	96.0	8.96	3	98.97	2.56	3	97.0	7.19
4	94.11	7.43	4	82.3	20.25	4	99.31	2.25	4	97.0	9.30
5	85.17	12.21	5	55.6	25.71	5	91.57	8.18	5	70.6	25.31
6	82.49	14.30	6	41.5	30.42	6	90.55	8.35	6	62.5	27.85
7	68.21	12.35	7	16.8	23.45	7	77.95	14.34	7	35.3	26.11
8	55.45	15.15	8	9.80	15.16	8	66.46	12.21	8	18.2	19.03

The mean values for both the groups on percentage of correct response show a consistent reduction pattern as the length of the syllables increase. However, the standard deviation of the correct responses in percentage is very high from syllable length 5 onwards. So, the consideration of number of correct responses for diagnosing should be cautioned. The repeated measures of ANOVA of group I showed that percentage of correct responses for 3 syllable nonwords were not significantly different from 2 syllable nonwords. Similarly 8 syllable nonwords were not significantly different than 7 syllables. However the decreasing pattern was noticed from 2-8 syllable nonwords (See Table 3 for significance values). The repeated measures of ANOVA of group II showed that percentage of correct responses for 4 syllable nonwords were not significantly different from 3 and 2 syllable nonwords. Likewise the performance on 6 syllable nonwords is not significantly poorer than 5 syllable nonwords (See Table 3 for significance values).

Table 3: *Significance values for all three parameters across groups*

%	G I	2>3	3>4	4>5	5>6	6>7	7>8
of		NS	.002	.001	NS	.000	.000
SC	G II	2>3	3>4	4>5	5>6	6>7	7>8
		NS	NS	.000	.001	.000	.000
%	G I	2>3	3>4	4>5	5>6	6>7	7>8
of AOR		NS	.004	.000	NS	.000	.000
	G II	2>3	3>4	4>5	5>6	6>7	7>8
		NS	NS	.000	NS	.000	.000
%	G I	2>3	3>4	4>5	5>6	6>7	7>8
of		NS	.000	.000	.055	.000	NS
CR	G II	2>3	3>4	4>5	5>6	6>7	7>8
		NS	NS	.000	NS	.000	.000

NS – Not significantly different, Values are significant at p= >.05 level of significance

In the present study the performance of nonword repetition reduced as function of nonword's length. As the length of the nonword increased from 2 till 8 syllables, the performance of all three measures (%SC, % AOR and % CR) reduced suggesting length of nonword as a major factor contributing to the performance. The reduction in scores as function of increase in length is not uncommon. The meta analysis study by Estes, Evans and Else-Quest (2007) considering four types of nonword repetition measures: (a) CNRep (Gathercole et al., 1994); (b) NRT (Dollaghan & Campbell, 1998); (c) lists using three- to four-syllable words (e.g., Edwards & Lahey, 1998; Kamhi & Catts, 1986); and (d) nonword sets designed by Montgomery and colleagues (e.g., Montgomery, 1995b, 2004) revealed that performance of participants degrade as length increases. Nonword repetition task developed by Shylaja (2010) and Standardization of Nonwords for 3-7 years (Swapna and Shylaja, in press) in Kannada also exhibited similar pattern. Results of this study enumerates that the performance deterioration is applicable even at lengthier nonwords (until 8 syllable used in this study).

The measures (% of syllable correct, % of accuracy of response and % of correct response) reveal that % of syllable correct is more reliable than the other two measures. The SD of % of correct response measure is too high as the length of syllable increase. This highly variable measure must be considered with caution when used to analyze nonwords performance for lengthier nonwords (i.e. from 5 and greater length). The application of percentage of accuracy of response too has to be taken with consideration since it is a subjective measure. The finding is consistent with the previous studies by Dollaghan & Campbell (1998) who suggested that the percentage of phonemes correctly repeated in NWR task should be considered instead of NWR accuracy for the validity enhancement of NWR task.

I. c. Correlation analysis

Table 4: *Correlation of % of vowels and consonants correct to % syllables correct (for combined age group)*

Syllable lengths	2	3	4	5	6	7	8
Vowel	0.75**	0.75**	0.66**	0.47**	0.77**	0.87**	0.91**
Consonant	0.75**	0.59*	0.73*	0.45**	0.50*	0.55*	0.71*

**- correlation value significant at <0.01 level of significance,
*-correlation value significant at <0.05 level of significance

A correlation analysis between percentages of syllable correct, percentage of consonant correct and percentage of vowel correct was done to identify the contribution of consonant and vowel errors reduction in percentage of syllable correct response. The analysis provided huge data and it was less conclusive. However, the general observation was that from syllable length 5 onwards vowel scores have contributed better to the % syllable correct score compared to consonant scores, suggesting the domination of consonant errors in lengthier syllables (from 5 to 8 syllable nonwords). The correlation values from syllable lengths 5 to 8 for consonants are negative suggesting that as the length increased the consonants percentage reduced. Thus, the consonants are negatively correlating with syllable lengths at higher syllable lengths. The results of present study is in consonance with study by Santos, Bueno, and Gathercole, (2006) who stated that consonant errors dominate vowel errors as the length of syllables increase and contributing to poor performance of lengthier nonwords.

Table 5: Mean and SD for substitution, deletion and addition error types for 7-13 years age group (combination of two groups).

Syllable length	Substitution		Deletion		Addition	
	Mean	SD	Mean	SD	Mean	SD
2	.61	2.40	0	0	0	0
3	.10	1.01	.10	1.01	.61	2.40
4	1.42	3.37	.60	1.94	.10	.50
5	4.43	4.32	1.27	2.33	.15	.70
6	3.43	5.53	1.20	2.36	.30	.81
7	19.23	7.74	4.39	3.52	4.14	3.07
8	28.18	6.82	9.70	4.24	4.63	5.85

I. d. Error analysis of typically developing children

Table 5, Shows that SD value for deletion and addition error types was too high, and needs to be considered while comparing and concluding data. Over all analysis revealed that substitution errors were significantly higher than deletion and addition errors for all syllable lengths from 2-8. Deletion errors were significantly higher than addition errors for syllable lengths 6, 7, and 8. Deletion errors were higher for syllable lengths 2, 3, 4 and 5 compared to addition errors, but they were not statistically significant. Results from previous studies also conformed to this pattern of substitution error dominating the deletion and addition errors.

Santos, Bueno, and Gathercole, (2006) also reported the same effect and they stated that Substitution errors are highest amongst the error types followed by deletion and addition errors. The frequency of all the error types increases as function of nonword length. Findings from study by Shylaja (2010) also were in consistent with results of the present study. Studies examined performance of school aged typically developing children and children with SLI revealed that the frequency of phoneme substitution was more than phoneme omissions for both the groups, but addition errors were infrequent (Edwards & Lahey, 1998; Marton & Schwartz, 2003; Montgomery, 1995)

II. Objective 2: Frequency and type of errors that differentiates children with SLI from children with NL.

Scores on error analysis for NWR performance of children with NL and SLI were compared to identify error types those differentiate children with SLI from NL.

II. a. Comparison between 7-10 years age group.

Table 6: Comparison of type of errors between NL and SLI group 7-10 yrs group

Length	Substitution		Reversals		Addition		Deletion		Regularization	
	NL	SLI	NL	SLI	NL	SLI	NL	SLI	NL	SLI
2	3	6.6	0	0	0	0	0	0	4	3
3	3.3	13.3	1.3	0	0	0	0	1	0	0
4	7	16.5	1	1.3	0	5	0	0	4	0
5	17	28	2	0	1	1	7.6	13.3	5	0
6	23	21	1	0	1	1	17.3	23.3	3	0
7	27	23.8	2	0	1	0	18	29.5	11	0
8	42	42	4.6	0	1.6	1.6	23	30.8	7.2	6.6

Table 6, show that SLI children from 7-10 years produce 50 % (approx) more substitution errors than children with NL from the same age group. This effect was observed only till 5 syllable length and the effect is negligible for 6, 7, and 8 syllable lengths. Length of syllables exhibits a pattern in deletion of syllables. There is a negligible deletion error until 4 syllable nonwords. The SLI group exhibited greater omission of syllables than children with NL in 5, 6, 7 and 8 syllable nonwords. Children with SLI did not differ from children with NL on reversal, addition and regularization errors.

Table 7, shows the comparison of type of errors between there is no consistent pattern in data of children with SLI and typically developing children in error analysis from age 10-13years. Questioning the validity of NWR task beyond 10 years should be dealt with caution since the study included only three participants in that age range and prevalence of NWR errors in SLI is not hundred percent (See meta-analysis by Estes, Evans and Else-Quest, 2007).

Table 7: Comparison of type of errors between NL and SLI group 11-13 yrs group.

Length	Substitution		Reversals		Addition		Deletion		Regularization	
	NL	SLI	NL	SLI	NL	SLI	NL	SLI	NL	SLI
2	0	0	0	0	0	0	0	0	1	0
3	1	2	1	0	0	0	0	0	0	0
4	1	5	1	0	0	0	1	0	4	3
5	6	6.6	3	2	0	1.3	9	1.3	3	0
6	20	18.6	1	0	0	1.1	14.6	12.2	5	3
7	23.3	26	2	1	1	0	19	15.9	9	8.3
8	37.3	39	2	1	4	8.3	21	23	8	3

To summarize the comparison of errors between children with SLI and NL, it is evident that children with SLI produce same quality of errors as children with NL, however the frequency is high. (Edwards & Lahey, 1998; Marton & Schwartz, 2003; Montgomery, 1995) also reported the similar findings. They also added that Children with SLI produce more substitution errors compared to deletion and addition errors which are in consistent with present study results.

Reversals and lexicalization errors are not significant in children with SLI in the present study. Similar findings were reported in the past where Lexicalization or Regularization errors were reported in normal (Dollaghan, Biber, & Campbell, 1995; Ellis Weismer & Hesketh, 1996) as well as SLI children (Edwards & Lahey 1998; Marshall, Harris & Van der Lely 2003). So we conclude the infrequent lexicalization errors observed in our SLI participants as non-significant marker of SLI.

Table 8: Comparison of SLI group with NL on Substitution, Deletion and Addition type of errors.

Syl length	2			3			4			5			6			7			8		
Error type	S	D	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D	A	S	D	A
Significantly SLI <NL	y	n	n	y	n	n	y	n	n	y	y	y	y	y	y	y	y	y	n	y	y

y- yes, n- no

Table 8, Shows those substitution errors of children with SLI were significantly higher than substitution errors produced by children with NL for syllable lengths 2, 3, and 4. From 5 syllable length onwards children with SLI produced significantly higher errors on all three error types, except that substitution errors at 8 syllable length was not significantly higher than normal group. It should be observed that even for lengthier nonwords SLI children produce significantly more errors compared to typically developing children, suggesting clinical marking ability of NWR even at 8 syllable levels.

III. Objective 3: Qualitative analysis of errors in children with SLI

Assimilation process is the major error type noticed in two of the SLI participants of the study aged eight and nine years respectively. The second prominent feature observed in overall NWR responses of children with SLI is intactness of word structure. See Table 9, for description of NWR of SLI children.

Table 9, shows the data from two children with SLI aged 8 and 9 years. The assimilation error types and intactness of word frame is noticed. All the assimilation errors are anticipatory (effect of following sound on preceding sound) where the initial sounds are influenced by following sounds.

Table 9*: Describes the errors noticed in 2 of SLI participants*

Response for Stimuli	**Assimilation errors**
p*ikasha* for thi/**p**a:/tcha	1^{st} syllable replaced with 2^{nd} syllable
d*hudhavova* for nu/**d**da/**d**ho/va	1^{st} syllable replaced with 2^{nd} syllable
d*hinnagetche* for gi/nna:/**d**he/tche	1^{st} syllable replaced with 3^{rd} syllable
k*udukutha* for dhu/vu/du/**k**o	1^{st} syllable replaced with 4^{th} syllable
v*u****g****a..a..u.thi* * for ju/tha/**v**a/dhu/**g**i	1^{st} and 2^{nd} syllables replaced with 3^{rd} and 5^{th} syllables respectively

*dotted utterances were distorted

The assimilation error types and intactness of word frame is noticed. All the assimilation errors are anticipatory (effect of following sound on preceding sound) where the initial sounds are influenced by following sounds. The data show no perseveratory assimilation errors and it was nonexistent in the data from SLI children who participated in the study. Theory of “segment -to-frame association” (Biran & Friedmann, 2004; Levelt, 1992) is adapted to explain findings such as intact word structure and anticipatory assimilation errors in present SLI qualitative data. The metrical frame includes the number of syllables and stress pattern of the word which are retained in the utterances of children with SLI. The segment portion consists of information on phonemes (consonants, vowels and clusters) and observed to be influenced by poor phonological short term memory. The results of the present study are in agreement with study by Marton & Schwartz, (2003). Morton and Schwartz (2003) claimed from their research that children with SLI produced 80% of segmental errors with no word structure change. According to this theory of phonological encoding in word retrieval, the segments and the structural frame of a word are processed separately, hence expected to be disturbed by different cognitive limitations. Study by Levelt, Roelofs, and Meyer, (1999) also supports that the segmental and metrical information are represented separately and accessed in parallel. The intact word frames in the NWR of the present study is consistent with segment to frame association principles (Biran & Friedmann, 2004; Levelt, 1992; Levelt, Roelofs, & Meyer, 1999; Marton & Schwartz, 2003).

One possible explanation for predominant anticipatory assimilation error type is that the phonological short term memory capacity is overwhelmed whilst retaining all segments of the nonword and placing them in appropriate metrical slots of word structure. The overwhelmed demand erased the sounds from initial part of nonwords and replaced them with later sounds of nonwords similar to recency effect in Serial position task (See Atkinson & Shiffrin, (1968) for explanation on serial position effect and recency effect). Along with recency erect and segment to frame association theory the assimilation errors in the present cases are explained. Children with SLI in the present study performed no different to children with NL on vowel errors. In fact, the relative intactness of vowel production helped SLI children to retain the word frame as children with NL.

Conclusions

The present study developed norm for NWR performance for age range 7-13 years using measures of percentage of syllable correct. Results are consistent with previous studies suggesting decreasing in percentage of syllable correct as function of nonword length. The error type analysis revealed more substitution errors followed by deletion and addition errors. Results of comparison of SLI data with normal data revealed that children with SLI differ from typically developing children predominantly on quantity of errors. However, in depth qualitative analysis revealed assimilation error types also and it was explained using segment to frame association hypothesis. The results of the study support the premise wit which the study was conducted i.e., nonword repetition performance could be treated as a true clinical marker of SLI.

References

Archibald, L. M. D., & Gathercole, S. E. (2006b). Short-term and working memory in SLI. *International Journal of Language and Communication Disorders, 41,* 675–693.

Atkinson, R. C., & Shiffrin, R. M. (1968). "Human memory: A proposed system and its control processes". In K. W. Spence, & T. J. Spence. *The Psychology of Learning and Motivation* (Volume 2). New York: Academic Press. pp. 89–195.

Bishop, D. V. M., North, T., & Donlan, C. (1996). Nonword repetition as a behavioral marker for inherited language impairment: Evidence from a twin study. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 37,* 391–403.

Chiat, S., & Roy, P. (2007). The preschool repetition test: An evaluation of performance in typically developing and clinically referred children. *Journal of Speech Language and Hearing Research, 50(2),* 429-443.

Chithra, R., Balaji, R. & Prema, K. S. (2007). Non-word repetition in Kannada – A clinical marker of specific language impairment? Research Report, Centre for Advanced Study in Linguistics at Osmania University, Hyderabad, 5-6 Jan.

Conti-Ramsden, G., & Hesketh, A. (2003). Risk markers for SLI: a study of young language learning children. *International Journal of Language and Communication Disorders, 38,* 251-63.

De Bree, E. (2007). Dyslexia and phonology: A study of the phonological abilities of Dutch Children at-risk of dyslexia. LOT dissertation-155, Utrecht.

Dollaghan, C., & Campbell, T. F. (1998). Nonword repetition and child language impairment. *Journal of Speech, Language, and Hearing Research, 41,* 1136–1146.

Dollaghan, C.A., Biber, M.E., & Campbell, T.F. (1995) Lexical influences on non-word repetition. *Applied Psycholinguistics, 16*: 211-222

Edwards, J., & Lahey, M. (1998). Nonword repetitions of children with specific language impairment: Exploration of some explanations for their inaccuracies. *Applied Psycholinguistics, 19,* 279–309.

Ellis Weismer, S., Tomblin, J. B., Zhang, X., Buckwalter, P., Chynoweth, J. G., & Jones, M. (2000). Nonword repetition performance in school-age children with and without language impairment. *Journal of Speech, Language, and Hearing Research, 43,* 865-878.

Gathercole, S. E., & Baddeley, A. D. (1989). Evaluation of the role of phonological STM in the development of vocabulary in children. *Journal of Memory and Language, 28,* 200–213.

Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection?. *Journal of Memory and Language, 29,* 336–360.

Gathercole, S. E., & Baddeley, A. D. (1996). The Children's Test of Nonword Repetition. London: Psychological Corporation.

Leonard, L.B. Children with Specific Language Impairment. Cambridge, MA: MIT Press, 1998.

Marton, K., & Schwartz, R. G. (2003). Working memory capacity and language processes in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 46,* 1138-1153.

Montgomery, J.W. (1995). Sentence comprehension in children with specific language impairment: The role of phonological working memory. *Journal of Speech and Hearing Research, 38,* 187-199.

Montgomery, J. W. (1995b). Sentence comprehension in children with specific language impairment: The role of phonological working memory. *Journal of Speech and Hearing Research, 38,* 187–199.

Montgomery, J. W. (2003). Working memory and comprehension in children with specific language impairment: What we know so far. *Journal of Communication Disorders, 36,* 221–231.

Rispens, J.E., & Parigger, E.M. (2010). Non-word repetition in Dutch-speaking children with specific language impairment with and without reading problems. *British Journal of Developmental Psychology, 28,* 177-188.

Prema, K. S., Prasitha, P., Savitha, S., Purushothaman, P., Chitra, R., & Balaji, R. (2010). Clinical Markers for Identification of Children with Specific Language Impairment (SLI). *Indian Journal of Applied Linguistics. 36,* 1-2,

Riches, N. G., Loucas, T., Charman, T., Simonoff, E. & Baird, G. (2011). Non-word repetition in adolescents with specific language impairment and autism plus language impairment: a qualitative analysis. *Journal of Communication Disorders, 44,* 23-36.

Sahlen, B., Reuterskiold-Wagner, C., Nettelbladt, U., & Radeborg, K. (1999) Non-word repetition in children with language impairment – pitfalls and possibilities. International *Journal of Language and Communication Disorders, 34*: 337-352

Santos, F.H., & Bueno, O.F.A. (2003). Validation of the Brazilian Children's Test of Pseudoword Repetition in Portuguese speakers aged 4-10 years. *Brazilian Journal of Medical and Biological Research, 36*: 1533-1547.

Santos, F.H., Bueno, S.E., & Gathercole. (2006). Errors in nonword repetition: Bridging short and long term memory. *Brazilian Journal of Medical and Biological Research, 39* (3), 371-885. http://dx.doi.org/10.1590/S0100-879X2006000300008

Shylaja, K. (2010). Nonword repetition in children with language impairment: An exploratory study. *Unpublished Master's Dissertation at University of Mysore.*

Shylaja, K., & Swapna, N. (In press). Standardization of 2-5 syllable nonword for 3-7 year children.

Shylaja, K., Amulya, P. R., & Swapna, N. (In press). Nonword repetition in children with Specific Learning Disability

SLI Consortium. (2004). Highly significant linkage to the SLI1 locus in an expanded sample of individuals affected by specific language impairment (SLI). *American Journal of Human Genetics, 94,* 1225–1238.

Stokes, S. F., Wong, A. M. Y., Fletcher, P., & Leonard, L. B. (2006). Nonword Repetition and Sentence Repetition as Clinical Markers of Specific Language Impairment: The Case of Cantonese. *Journal of Speech, Language, and Hearing Research, 49,* 219-236.

Vasanthi, A., & Prema, K. S. (2001). Delayed speech and language - A myth? *The Journal of the Indian Speech and Hearing Association, 15,* 85-90.

LEXICAL PROCESSING IN 8-10 YEAR OLD CHILDREN: EVIDENCE THROUGH BEHAVIORAL AND ERP MEASURE

[1]Dhatri S. Devaraju, [2]Vrinda R., [3]Jayashree C. Shanbal, [4]Mamatha N. M. & [5]Gopi Sankar R.

Abstract

The primary aim of the present study was to compare the behavioral with event-related potential (ERP) correlates of implicit phonological processing during the recognition of spoken words in typically developing children. Children in the age range of 8-10 years were investigated with both behavioral and electrophysiological measures. The behavioral response and N400 were recorded using 30 pairs of words and non-words presented auditorily. The reaction time and accuracy for words and non-words were considered along with the peak amplitude and latency of N400 peak for the analysis. The results showed a significant difference in both reaction time and accuracy for words and non-words. There was also significant difference noted in the peak amplitude and latency measure for words and non-words. When the behavioral measures were correlated with amplitude and latency of N400, the reaction time correlated very well with amplitude and latency than the accuracy measure. Thus, indicating that the peak amplitude and latency measure of N400 could serve as an important tool which reflects the integration of semantic information in children at a lexical processing level. The present study also revealed a significant difference in the performance of the children on tasks which were observed to be lateralized to channels in the left hemisphere. This indicated that for lexical decision, involves a higher level language (semantic) processing in children lateralized to the left hemisphere. The present findings explain that the behavioral and neurophysiological measures are equally important and may not provide a complete picture when each of the measure is carried out alone.

Key words*:* *Lexical decision, Reaction time, Accuracy, Event-related potential (ERP), N400*

Phonology is a structural aspect of language which involves the sounds of a language and their organization. It is well known that there is a causal connection between children's phonological skills and their acquisition of reading and spelling. Data from both normally developing and atypically developing children demonstrates that the quality of a child's phonological representations is important for their subsequent progress in literacy. This relationship has been found across all languages so far studied, for both normal readers (Bradley & Bryant, 1983; Hoien, Lundberg, Stanovich & Bjaalid, 1995; Siok & Fletcher, 2001), and children with dyslexia (Bradley & Bryant, 1983; Bruck, 1992; Landerl, Wimmer, & Frith, 1997; Porpodas, 1999). However, the focus on understanding whether these deficits are at a perceptual level, awareness level or cognitive level has been attempted through offline behavioral tasks such as metaphonological or phonological awareness tasks. Studies in the literature have investigated implicit phonological representations using different methods such as lexical gating, priming, syllable similarity tasks etc in both typically developing individuals and reading-impaired populations.

Lexical decision task is one of the most popular tasks employed to study word processing, both in the auditory and the visual modality. In an auditory lexical decision task, the participants are presented with spoken stimuli and are expected to decide whether the stimuli form is a word or not. In majority of the studies reported in the literature, data collected from the typically developing children was compared to atypically developing children, and the results revealed that the second group performed poorer compared to the first group.

Taroyan and Nicolson (2009) studied the behavioral correlates of lexical decision processes in English speaking nine normal adolescents. They showed significantly longer response times and lower accuracy for the pseudowords/non-words. Sela et al. (2011) did a study on twenty two adults (age 25±2.48 years) and twenty five 7th grade children (age 12.65±0.467 years) using a visual lexical decision task and found that younger group exhibited slower reaction time as compared to adults. They also found that compared to words both the groups exhibited longer reaction time for pseudo words. With respect to accuracy, they

[1]Research Officer, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: dhatri2612@gmail.com, [2]Research Officer, AIISH, Mysore-06, [3]Lecturer in Language Pathology, AIISH, Mysore-06, Email:jshanbal@gmail.com, [4]Lecturer in Audiology, AIISH, Mysore-06, Email: mamms_20@gmail.com,& [5]Research Officer, AIISH, Mysore-06, Email: sankaj2002@gmail.com

found that accuracy was higher for pseudo words in both the groups. Pizzioli and Schelstraete (2007) investigated lexical processing in children using a lexical decision task to evaluate the accuracy and speed of spoken-word recognition. They found greater errors on pseudo-words compared to real-words. With respect to reaction time, they found a significant effect on word type, with longer reaction times for pseudo-words than real words.

The above mentioned studies included tasks which only revealed the end performance of subjects; however it has often been found that an understanding of the complex neuro-cognitive processes involved in language processing would be difficult through such offline behavioral tasks. There is lack of adequate methodologies to understand online, real-time language processing in the brain during complex neuro-cognitive processes throughout the linguistic skills development (Osterhout & Holcomb, 1995). The electrophysiological recording of event-related potentials (ERPs) of the brain is one of the few methods which are well suited for the investigation of real-time language processing in the brain. N400 is one such ERP mostly used and found to be associated with language processing. The N400 typically is the most negative peak which occurs at approximately 400 ms post-stimulus (Kutas & Hillyard, 1980a, 1980b, 1980c, 1984; McPherson & Ballachanda, 2000). Kutas and Hillyard in their very first studies in 1980s used sentences that ended with semantically inappropriate word to elicit stronger N400. Osterhout and Holcomb (1993) also found that grammatically incorrect sentences elicited larger N400 responses as compared to grammatically correct sentences. Polich (1985) investigated using different set of stimulus such as a series of words that were interspersed with occasional semantically inappropriate word and obtained N400 in both selective and active attention.

The N400 component has been elicited in response to semantic errors for both visual and auditory modalities (Holcomb & Neville, 1990; McCallum, Farmer, & Pocock, 1984; Bessen, Faita, Czternasty, & Kutas, 1997; Kutas & Hillyard, 1980a, 1980b, 1980c, 1983, 1984; Swaab, Brown & Hagoort, 2003). The studies conducted by Connolly, Byrne, and Dywan (1995) and Byrne, Dywan, and Connolly (1995a, 1995b) indicated that the N400 could be elicited by semantic errors in both children and adults. However, there are fewer studies done on school aged children reporting N400 (Byrne, Conolly, MacLean, Dooley, Gordon & Beattie., 1999; McCleery, Ceponiene, Burner, Townsend, Kinnear & Schreibman, 2010). Byrne, Conolly, MacLean, Dooley, Gordon, and Beattie (1999) found that the N400 amplitude was significantly higher for incongruent picture-word pair than congruent picture-word pair. This N400 effect was found in all the four age groups such as 5 to 6 years, 7 to 8 years, 9 to 10 years, and 11 to 12 years involving a total of 56 typically developing children. Coch, Maron, Wolf and Holcomb (2002) studied N400 for words in 10 to 11 years aged children. But the stimulus consisted only of visual and pictorial representations of the words. For auditory presentation of stimuli, there was an earlier and more prolonged effect of N400 when compared to visual presentation, which was slightly lateralized to the right hemisphere during auditory presentation (Holcomb & Neville, 1990). However, there are very few studies investigating the N400 effects using only the auditory stimuli, especially how each word with and without meaning elicit N400 in school going typically developing children.

Hence the present study investigated the implicit phonological processing using event-related potential (ERP) correlates during the recognition of spoken words in typically developing children. It is important that an assessment of phonological processing is done at an explicit as well as implicit level in order to understand the relative difficulty of a child at various levels such as lexical access, decoding, phonemic categorization and awareness. Thus, the aim of the present study was to understand the implicit phonological processing comparing the behavioral correlates with event-related potential (ERP) correlates during the recognition of spoken words in typically developing children.

Method

Participants

Sixteen typically developing children in the age range of 8-10 years were selected for the study. They were divided into two subgroups of ages 8-9 years (Males=2, Females=6) and 9-10 years (Males=2, Females=6) of 8 children in each subgroup. All the children were screened using the WHO ten disability checklist (cited in Singhi, Kumar, Prabhjot & Kumar, 2007) and Developmental screening test (Bharath Raj, 1983) to rule out any sensory, motor, behavioural, or intellectual deficits. ELTIC (English Language Test for Indian Children, Bhuwaneshwari, 2010) was administered to assess the English language skills of the children and whoever passed the test were considered for the study. Native language of all the participants was Kannada with English as the medium of instruction in school. All the participants had air conduction thresholds and bone conduction thresholds within 15 dB HL at octave frequencies from 250 Hz - 8 kHz and 250 Hz - 4 kHz respectively (ANSI S3.21, 2004). There were no symptoms of otological and neurological disorders. There was no history of any middle ear pathology. "A" type tympanogram with normal ipsilateral and contralateral acoustic reflex thresholds were obtained for all the participants. Participants with good speech perception in noise with SPIN scores of more than 60% were considered for the study.

Instrumentation

A calibrated two-channel Madsen Orbiter-922 clinical audiometer (version 2) with TDH-39 headphones and Radio ear B-71 bone vibrator was used to establish air conduction and bone conduction pure tone thresholds respectively. A calibrated Grason Stadler Inc.-Tympstar immittance meter (version 2) was used to rule out middle ear pathology. Compumedics Neuroscan instrument with Scan™ 4.4 module along with Quick Cap®, Model C190 was used for recording of cortical evoked event related potentials. And Stim^2 version 4.4 module was used to deliver the stimulus. A personal computer with DMDX software was used to carry out behavioral task.

Preparation of stimuli

A list of 100 stimuli was prepared which included 50 pairs of words - non words combination (e.g. leaf-meaf). All the words selected were picturable, which occur in the vocabulary of 8-10 year old children. The non-words were prepared by substituting the initial phoneme of the word conforming to the rules of English. It was also made sure that the changed phoneme in the non-word accounted to the frequency spectrum of the initial phoneme of the word. This stimuli list was given to five experienced judges (Speech-Language Pathologists and Audiologists) for familiarity rating on a three- point scale as 'highly familiar', 'familiar', and 'unfamiliar'. Out of the 50 word-non word pairs, 30 pairs which were rated as highly familiar or familiar by at least three out of the five judges were selected. The selected 30 pair of words was recorded by 4 male speakers. The audio samples were given for goodness rating to 5 audiologists. The audio samples were rated on a 0-5 rating scale, 5 representing the higher quality and 0 representing the poorest. The ratings were done by considering the parameters: intelligibility, clarity, loudness, naturalness and the overall quality of the audio sample. The audio sample which got the highest rating for all the parameters was selected as the final stimulus.

Stimuli presentation

Both behavioral task and ERP measure were considered separately for the study. For the behavioral task, the 30 recorded words were programmed on DMDX software for presentation. The presentation of the stimuli were controlled and was presented through the DMDX software version 3.13.0 (Forster & Forster, 2003) for measuring the reaction times (RTs) and accuracy of responses. A practice session with 10 stimuli (5 words & 5 non-words) was given to familiarize the subjects with the instructions and task. Stimuli words in each list was randomized and presented.

For the ERP recording, the stimuli were presented using Gentask module in Stim^2. Each word and non-word was presented twice in a list. Thus a list consisted of 120 stimuli. A total of 4 lists were made arranging the words and non-words in a random order. Each participant was presented two out of the four lists randomly during the ERP recording. The inter stimulus interval between any two word in a list was 3000 ms. Different trigger values were specified for word and non-word respectively. The stimuli were presented binaurally at 60 dB SPL using ER-3A insert earphones.

Procedure

Behavioral task

All the participants were tested individually in a room. The recorded stimuli were presented using a head phone. The subjects were instructed as follows: "You will hear words. It may be true word/ meaningful word or false word/non-word/ non meaningful word. You have to press '1' for a meaningful word and '0' for a non-meaningful word as soon as you hear the stimuli." Reaction times were recorded to the nearest millisecond and stored in the computer and error rates were calculated

A '+' sign appeared on the screen for 300 ms before the stimuli was presented. This would help the subject to be vigilant for the upcoming stimuli. The target word was then presented while the screen remained blank and remained so for the next 4000 ms or till the subject responded, whichever occurred first. If the subject failed to respond to a target within 4000 ms, that item was recorded as an error. For the ERP measure, the subjects were considered with a gap of minimum 10 days after the behavioral test to avoid any learning effect.

ERP task

The cortical event related potentials were recorded using SynAmps[2]. The participants were seated comfortably in a reclining chair. The Quick Cap consisting of 64 sintered silver chloride electrodes was used for recording evoked potentials. The event related potential was recorded from 15 electrode sites of 10-20 system: Fz, FCz, Cz, CPz, Pz, F3, F4, C3, C4, C5, C6, T7, T8, P3 & P4 (Jasper, 1958). Linked mastoid was used as a reference/ active electrode. An electrode site between FPz and Fz was used as ground electrode. The electrode impedance was lesser than 5kΩ. The participants were shown a cartoon video while placing the electrodes to distract their attention and facilitate electrode placement. A blunt needle was used to clean the electrode site. Quick Gel™ filled up in the syringe was used as conduction gel to bridge the scalp with the electrode surface. A continuous EEG data was recorded and digitized at 1000 Hz. The data was low pass filtered at 100 Hz, and high passing DC. The time window of 1500 ms with a pre stimulus interval of 200 ms was considered for online averaging. The corresponding trigger values as given in Stim[2] was entered such that the responses recorded will be time locked with the stimulus given. To maintain the attention of the participants, they were instructed to press button no.1 on a response box if they hear meaningful word and to press no. 2 if they hear non-meaningful word. Two recordings were obtained to check for the replicability of the waveforms. The total duration of the testing was one hour per participant.

Scoring and Analysis

The reaction time was tabulated in milliseconds. All wrong responses and those responses which exceeded the 4000 ms frame duration were eliminated from the data analysis. This was done for both subgroups. Accuracy was calculated for both words and non-words. A score of '1' was provided for each correct response and '0' for wrong/ absent response. The data was coded and tabulated and then subjected to statistical analysis.

Offline analysis of ERP waveforms

The continuous EEG waveform was DC offset corrected with a polynomial order of two to decrease the drift in the waveforms. The DC corrected waveforms were band pass filtered at 0.1-10 Hz. The continuous filtered EEG waveform was epoched from -100 to 1500 ms and was baseline corrected. Finally the epoched files were averaged to obtain different waveforms for words and non-words. Only N400 peak was considered for the analysis. The negativity between 400 to 800 ms was marked as the N400 peak. The amplitude and latency of N400 for 15 channels was tabulated for further statistical analysis. The data was analyzed using the Statistical Package for the Social Sciences (SPSS) version 17.1 software. Independent Sample t-test was done to compare the performance of children for RT and accuracy for words and non-words across the two subgroups. Paired Sample t-test was done to analyze the performance of children for RT (in ms) and accuracy measure for words and non-words separately. Kolmogorov-Smirnov test was done to check for the normality of the ERP data. Two way repeated measure analysis of variance (ANOVA) was carried out with condition (word, non-word) and channels (15 channels) as repeated measures variables and both N400 peak amplitude (in microvolts) and latency (in milliseconds) as dependent variable. Paired sample t-test was done to compare the differences of amplitude and latency of N400 across channels for words and non-words. Karl Pearson's correlation was done to study the relation between behavioral measures (including RT & accuracy) and N400 measures (including amplitude & latency).

Results

The behavioral correlates [such as reaction time (RT) and accuracy] for words and non-words were compared with event-related potential (ERP) correlates (such as the absolute peak amplitude and latency of N400 peak) in order to study the implicit phonological processing during the recognition of spoken words in typically developing children. Independent Sample t-test was done to compare RT and accuracy for words and non-words across two subgroups. There was no significant difference between two groups in reaction time for words and non-words ($t=0.69$, $p=0.49$ & $t=0.64$, $p=0.53$ respectively, at p value 0.05). Also, no significant difference was noted between the two subgroups when accuracy for words and non-words were considered ($t=-0.34$, $p=0.74$ & $t=-0.21$, $p=0.84$ respectively, at p value 0.05). As there was no significant difference noted between the two sub groups, 8-9 year old and 9-10 year old were clubbed into one single group of 8-10 years age.

Performance of children on behavioral measure and ERP (N400) measure

For the behavioral measure, Paired Sample t-test was done to analyze the RT (in ms) and accuracy measure for words and non-words separately.

The mean and standard deviation (SD) for reaction time and accuracy for performances of children on words and non-words were obtained which is shown in Table 1.

Table 1: *Mean and SD for performances on words and non-words*

		Mean	SD
RT (in ms)	Words	705.13	205.85
	Non-words	946.17	340.82
Accuracy	Words	25.69	2.12
	Non-words	21.81	3.47

Analysis of results from Table 1 indicated that the reaction time for words (Mean=705.13ms; SD=205.85) was shorter compared to non-words (Mean=946.17ms; SD=340.82). That is, the participants responded faster for words than for non-words. With respect to accuracy, it was found that the performance was better for words (Mean=25.69; SD=2.12) than non-words (Mean=21.81; SD=3.47). This indicated that more errors were observed for performance on non-words than words. Analysis of results also revealed that there was a significant difference for RT between words and non-words [$t=-4.982$, ($p<0.05$)]. A significant difference was also found for accuracy between words and non-words [$t=4.453$, ($p<0.05$)].

It was also observed that, majority of the children made errors on the non-word stimuli “drush” and “lesk” followed by other non-words such as “prapes”, “pum”, “galk”, “shirl”, “plass”, “gaste”, “dion”. This means that children identified these non-words as true words. Considering words, the stimuli “bus” had the maximum errors followed by the words “bird” and “brush”. This indicates that the subject erroneously identified these words as non-words.

The data of ERP measure was also analyzed statistically. For this purpose the latency and amplitude of the N400 peak at 15 different channels were considered separately. The mean and SD of amplitude and latency for both words and non-words at 15 different channels are shown in Table 2. The analysis of results from Table 2 indicated that the mean N400 amplitude for non-words was consistently higher than words indicating the N400 effect.

Table 2: *Mean and SD of peak amplitude and latency of N400 for words and non-words at 15 different channels*

	Words				Non-words			
	Amplitude(in µV)		Latency(in ms)		Amplitude(in µV)		Latency(in ms)	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
C3	-21.01	8.00	512.00	55.91	-24.37	6.32	542.18	76.63
C4	-21.91	8.72	532.06	117.99	-24.98	8.19	557.56	94.32
C5	-19.80	8.57	539.31	51.27	-23.82	7.81	565.25	68.48
C6	-18.83	7.57	527.62	90.64	-20.87	6.75	544.18	81.90
CPz	-12.30	6.25	473.00	72.94	-14.27	3.80	504.81	95.26
Cz	-15.98	7.05	485.37	74.54	-18.79	5.91	533.06	83.93
F3	-29.05	9.31	531.06	74.10	-35.52	9.26	585.56	70.01
F4	-28.88	7.78	561.81	86.76	-32.84	8.88	588.68	83.96
FCz	-20.86	8.20	504.81	73.29	-26.05	8.15	565.62	87.73
Fz	-27.23	8.90	569.43	104.35	-33.24	9.53	597.87	82.18
P3	-12.43	6.90	478.31	67.68	-14.53	4.66	507.62	80.78
P4	-13.47	6.71	484.00	82.67	-14.73	4.60	506.81	87.59
Pz	-10.20	5.61	464.68	66.86	-11.57	3.68	482.06	81.42
T7	-14.17	7.98	611.50	84.40	-17.87	8.29	629.06	67.45
T8	-16.09	5.57	603.50	105.57	-17.25	5.06	630.75	81.34

The results from Table 2 also show that the mean peak latency for words is shorter when compared to non-words. It suggests that the children show longer processing time for non-words than words generally. This might also suggest that there might be greater number of generator sites involved in non-word processing than in word processing leading to higher amplitude values for non-words.

The ERP data (includes N400 peak amplitude and latency) was checked for normality using Kolmogorov-Smirnov test and was found that the data was significantly normal ($p>0.05$). The data with sixteen children across fifteen channels and between two conditions (word-nonword) were further analyzed using Two-way repeated measure analysis of variance (ANOVA). Two-way repeated measure ANOVA was carried out to analyze the N400 peak amplitude (in microvolts) as dependent variable with condition (word, non-word) and channels (15 channels) as repeated measures variables. The results indicated that there was a significant main effect for condition [$F(1,15)=14.521$, at $p< 0.05$)] and channels [$F(14, 210)=41.251$, at $p<0.01$]. A significant interaction effect was also found between condition and channel [$F(14,210) = 6.454$, at $p<0.01$]. A Paired sample t-test was done to analyze and compare the differences of amplitude across channels for words and non-words. The results showed a significant difference for amplitude between words and non-words for the channels: C3, C4, C5, Cz, F3, F4, FCz, Fz, P3 and T7 (t=2.85, 2.51, 4.37, 2.65, 5.32, 3.06, 4.68, 5.97, 2.39, & 3.82 respectively, at $p<0.05$ level).

Similarly, the data was analyzed for N400 latency measure using two way repeated measure ANOVA with condition (word, non-word) and channels (15 channels) as repeated measure variables and N400 peak latency (in milliseconds) as the dependent variable. The main effect of condition [$F(1, 15)=7.440$, at $p<0.05$] and channel [$F(14,210)= 14.189$, at $p<0.01$] was significant. But there was no significant interaction effect of condition with channels for latency [$F(14,210)= 0.879$, $p>0.05$]. Paired sample t-test was carried out to compare the differences in latencies across channels for words and non-words. The latency of N400 peak for words was significantly shorter compared to non-words for the channels: C3, Cz, F3 and FCz (-2.56, -2.67, -2.92 & -2.68 respectively, at $p<0.05$).

Correlation between behavioral and N400 measures

Karl Pearson's correlation was done to study the relation between behavioral measures (including RT & accuracy) and N400 measures (including amplitude & latency). There was significant positive correlation of RT and N400 peak amplitude for words at the channels C5, F3 and T7 (r= 0.516, 0.533, & 0.530 respectively, at $p<0.05$). But when reaction time was correlated with N400 peak amplitude for non-words, there was no significant correlation at any channels except a positive correlation at T7 (r=0.537, at $p<0.05$). There was no significant correlation between N400 peak amplitude and accuracy for words. When peak latency was correlated with RT for words, there was no significant correlation except a positive correlation at T8 (r=0.595, $p<0.05$). When peak latency was correlated with RT for non-words, there was no significant correlation except at T8 which was positive (r= 0.542, at $p<0.05$). There was significant negative correlation between peak latency and accuracy for words at channels C5, F3 and T7 (r=-0.664, -0.598 & -0.568 respectively, at $p<0.05$). There was also significant positive correlation between peak latency and accuracy for non-words at channels C5 and F3 (r=0.665 & 0.609, at $p<0.05$). There was no significant correlation between non-words peak amplitude and non-words accuracy for any of the channels.

The difference in the amplitude for words and non-words is termed as N400 effect. The N400 effect was correlated with the difference in reaction times for words and non-words using Karl Pearson's correlation. The results showed a significant negative correlation of reaction time difference with the N400 effect in channels such as C3, C4, CPz, Cz, F3, F4, FCz, P4 and Pz (Table 3). But when the N400 effect and the difference in peak latencies for words and non-words was correlated with the difference in accuracy for words and non-words, there was no significant correlation seen ($p>0.05$). The difference in peak latencies of N400 for words and non-words was also correlated with the behavioral differences in reaction time for words and non-words using Karl Pearson's correlation. The results indicated a significant negative correlation in few channels such as C4, C6, F4 and Fz (r= -0.775, -0.539, -0.543 & -0.505 respectively, at $p<0.05$).

Table 3: *Pearson's correlation coefficients for reaction time difference and peak amplitude difference across significant channels*

Reaction time difference	C3	C4	CPz	Cz	F3	F4	FCz	P4	Pz
Pearson Correlation	-.517*	-.595*	-.565*	-.633**	-.664**	-.530*	-.658**	-.551*	-.514*
Significance	.040	.015	.023	.009	.005	.035	.006	.027	.041

* Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level

Discussion

The accuracy and reaction time for the recognition of words and non-words was evaluated using a behavioral (lexical decision) task. As previously evidenced in literature reaction time was less for words as compared to non-words (Pizzioli & Schelstraete, 2007; Taroyan & Nicolson, 2009; Sela et al., 2011). Also, results of the previous studies (Pizziolo & Schelstraete, 2007 & Taroyan & Nicolson, 2009) indicated a lower accuracy for pseudo words. The results of the present study confirm those of the above studies but contraindicated with the study by Sela et al (2011) which showed higher accuracy for pseudo words. Figure 1 shows grand averaged ERP waveforms of 16 subjects for words and non-words. From the Figure 1, it can be evidenced that the mean peak amplitude of N400 for non-words was greater than that for the words. This indicates that there was N400 effect for the words even when it is presented auditorily alone. The results also showed that the N400 effect can be seen for auditory stimuli without any semantic priming. It can also be seen from the Figure 1 that the N400 peak is broader and of more amplitude in frontal channels compared to other channels. There is no much difference in the amplitude of N400 for words and non-words in the parietal channel. In temporal channels such as T7 and T8, T7 shows N400 effect while there is very lesser N400 effect seen in T8 when compared to T7. The coronal channels show good N400 effect but not as much as the frontal channels.

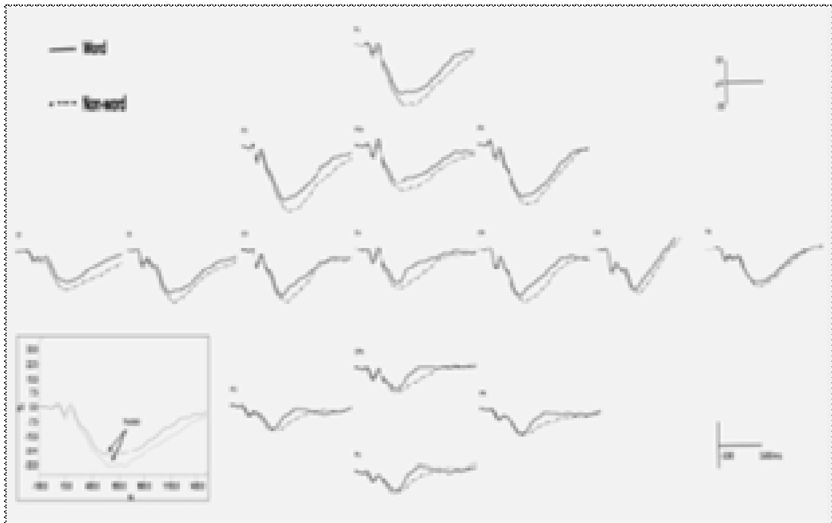

Figure 1: *Grand average ERP waveform at 15 different channels for both words and non-words. Waveform enlarged at Fz showing N400 in the bottom left*

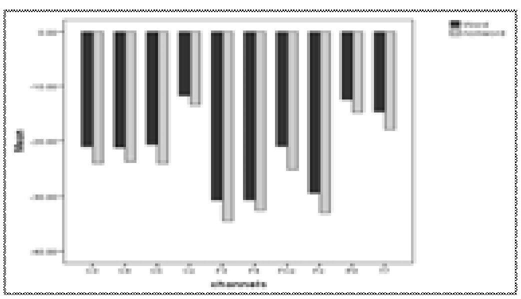

Figure 2: *Mean N400 amplitude for words and non-words at different channels which were significant*

Figure 2 shows mean N400 amplitude for words and non-words at channels which were significant. The N400 effect for amplitude was seen in the frontal, fronto-central, central and one of the parietal channels, as shown in Figure 2, which is consistent with the previous researches (Byrne et al., 1999; Friedrich & Friederici, 2006; Holcomb & Neville, 1990; Kutas & Federmeier, 2000; Kutas & Van Petten, 1998; Landi & Perfetti, 2007; Lau, Almeida, Hines & Poeppel, 2009; McCleery et al., 2010). But along with these channels, the N400 effect is also seen in temporal channel. This might be because of the only auditory mode used for presentation of the stimuli. The previous studies have either used visual stimuli or both auditory and visual stimuli for presentation of words (Connolly et al., 1995; Byrne et al., 1995a, 1995b; Byrne et al., 1999; McCleery et al., 2010). As can be evidenced from Figure 1, when frontal channels (F3 & F4) were considered the effect was seen in both right and left hemisphere channels. When mid coronal channels (C3, C4, C5, C6, T7, T8) were investigated there was more activity towards the left hemisphere compared to right as the N400 peak amplitude was more in left hemisphere channels than right hemisphere channels. There was only left hemisphere activation when parietal and temporal channels were investigated as there was significant amplitude difference in P3 and T7 respectively. This result is contradicting to the study by Holcomb and Neville (1990), who opined that there is earlier and more prolonged effect of the N400 for auditory presentation, slightly lateralized to the right hemisphere. But in this study priming task was used in auditory mode and in the present study there was no prime that was used.

When the N400 peak latency was considered only frontal and central channels had significant difference between words and non-words. The mean peak latencies for non-words were significantly longer than the words as shown in Figure 3. This suggests that the processing at these sites takes place for longer time.

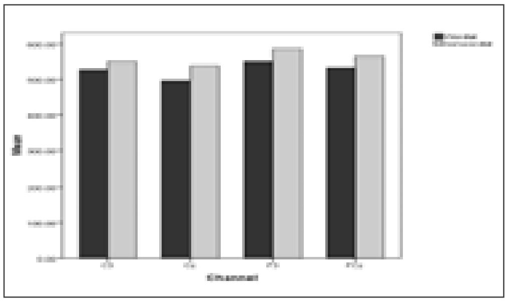

Figure 3: *Mean N400 latency for words and non-words at channels which were significant*

Correlation of behavioral and electrophysiological measures showed negative correlation of N400 effect with the difference in reaction times. This suggests that greater the N400 effect better is the performance of the individual on lexical decision. The channels which correlated were more of frontal, central and parietal in origin. Both right and left hemisphere channels equally contributed as there was good correlation with both the hemisphere channels in frontal and central regions. But there was strong correlation seen in F3, Fz and Cz channels indicating better processing at these sites. When parietal channels were correlated, there was more of right hemisphere participation and also the midline (Pz).

Summary and Conclusions

The present study investigated the comparison of performance of children on behavioral and N400 measures. The findings of the present study revealed that measures of N400 such as peak amplitude and latency measures correlated with reaction time significantly than accuracy measures. Thus indicating that peak amplitude and latency measure of N400 could serve as an important tool which reflects the integration of semantic information in children at a lexical processing level. The present study also revealed that significance in performance on the tasks was observed to be lateralized to channels in the left hemisphere. This indicates that since the tasks involved though are indicating only a lexical decision, this task also involves a higher level language (semantic) processing in children. Whereas, a few other studies conducted in adults indicated similar paradigm with results lateralized to the right hemisphere. A synthesis of results of present study and previous studies indicate that this could be a developmental shift of semantic processing in children to adults when tasks are learnt initially with the aid of language processing in left hemisphere and the task becomes more automatic in adults who process through the right hemisphere.

The present findings to some extent explain that the behavioral and neurophysiological measures are equally important, but behavioral measures may not be as adequate in revealing subtle differences as ERP measures. Direction for future research through the present study would be to investigate these differences in the clinical population such as children with dyslexia who are found to show difficulties at various language levels, phonological processing being one of them. This attempt would facilitate development of neurocognitive language assessment batteries or tools that may be more sensitive compared to other less sensitive methods.

Limitation of the present study is that the sample size was small. Similar study on a larger population at wider age ranges would facilitate a better understanding of development of phonological processing skills in children.

References

American National Standards Institute (2004). *Methods for manual pure-tone threshold audiometry* (ANSI S3.21-2004). New York.

Bessen, M., Faita, F., Czternasty, C., & Kutas, M. (1997). What's in a pause: Event-related potential analysis of temporal disruptions in written and spoken sentences. *Biological Psychology, 46,* 3-23.

Bharat Raj. J. (1983). Developmental Screening Test (DST). Mysore: Swayamsiddha.

Bhuvaneshwari, N., & Shanbal, J. C. (2010). ELTIC (English Language Test for Indian Children). *Student Research at AIISH, Mysore (Articles based on dissertation done at AIISH), Vol. VIII,* 182-189.

Bradley, L., & Bryant, P. E. (1983). Categorising sounds and learning to read: A causal connection. *Nature*, *310*, 419–421.

Bruck, M. (1992). Persistence of dyslexics' phonological awareness deficits. *Developmental Psychology, 28*, 874–886.

Byrne, J. M., Conolly, J. F., MacLean, S. E., Dooley, J. M., Gordon, K. E., & Beattie, T. L. (1999). Brain activity and language assessment using event-related potentials: Development of a clinical protocol. *Developmental Medicine and Child Neurology*, *41*, 740-747.

Byrne, J. M., Dywan, C. A., & Connolly, J. F. (1995a). An innovative method to assess the receptive vocabulary of children with cerebral palsy using event-related brain potentials. *Journal of Clinical and Experimental Neuropsychology. 17,* 9-19.

Byrne, J. M., Dywan, C. A., & Connolly, J. F. (1995b). Assessment of children's receptive vocabulary using even-related brain potentials: Development of a clinically valid test. *Child Neuropsychology. 1,* 211-223.

Coch, D., Maron, L., Wolf, M., & Holcomb, P. J. (2002). Word and picture processing in children:

An event-related potential study. *Developmental Neuropsychology, 22,* 373-406.

Connolly, J. F., Byrne, J. M., & Dywan, C. A. (1995). Assessing adult receptive vocabulary with event-related potentials: An investigation of cross-modal and cross-form priming. *Journal of Clinical and Experimental Neuropsychology. 17,* 548-565.

Friedrich, M., & Friedrici, A. D. (2006). Early N400 development and later language acquisition. *Psychophysiology, 43,* 1-12.

Hoien, T., Lundberg, L., Stanovich, K. E., & Bjaalid, I. K. (1995). Components of phonological awareness. *Reading & Writing, 7,* 171–188.

Holcomb, P. J., & Neville, H. (1990). Auditory and visual semantic priming in lexical decision: A comparison using event-related potentials. *Language and Cognitive Processes, 5,* 281-312.

Jasper, H. H. (1958). The ten-twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology, 10,* 371-375.

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences, 12,* 463-470.

Kutas, M., & Hillyard, S. A. (1980a). Event-related brain potentials to semantically inappropriate and surprisingly large words. *Biological Psychology, 11,* 99-116.

Kutas, M., & Hillyard, S. A. (1980b). Reading between the lines: Event-related brain potentials during natural sentence processing. *Brain and Language, 11*, 354-373.

Kutas, M., & Hillyard, S. A. (1980c). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207,* 203-205.

Kutas, M., & Hillyard, S. A. (1983). Event-related brain potentials to grammatical errors and semantic anomalies. *Memory and Cognition, 11,* 539-550.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature, 307,* 161-163.

Kutas, M., &Van Petten, C. (1998). Event-related brain potentials studies of language. *Advances in Psychphysiology, 3,* 139-187.

Landerl, K., Wimmer, H., & Frith, U. (1997). The impact of orthographic consistency on dyslexia: A German-English comparison. *Cognition, 63*, 315–334.

Landi, N., & Perfetti, C. A. (2007). An electrophysiological investigation of semantic and phonological processing in skilled and less skilled comprehenders. *Brain and Language, 102,* 30-45.

Lau, E., Almeida, D., Hines, P., & Poeppel, D. (2009). A lexical basis for N400 context effects: Evidence from MEG. *Brain and Language, 111(3),* 161-172.

McCallum, W. C., Farmer, S. G., & Pocock, P. K. (1984). The effect of physical and semantic incongruities on auditory event-related potentials. *Electroencephalography and Clinical Neurophysiology, 59*, 447-488.

McCleery, J., Ceponiene, R., Burner, K. M., Townsend, J., Kinnear, M., & Schreibman, L. (2010). Neural correlates of verbal and nonverbal semantic integration in children with autism spectrum disorders. *Journal of Child Psychology and Psychiatry, 51(3),* 277-286.

McPherson, D. L., & Ballachanda, B. (2000). Middle and long latency auditory evoked potentials. In R. Roeser, M. Valente, & H. Hosford-Dunn (Eds.), *Audiology: Diagnosis* (pp. 471-501). New York: Thieme Medical Publishers.

Osterhout, L., & Holcomb, P. J. (1993). Event-related potentials and syntactic anomaly: Evidence of anomaly detection during the perception of continuous speech. *Language and Cognitive Processes, 8*, 413-437.

Osterhout, L., & Holcomb, P. J. (1995). Event-related potentials and language comprehension. In M. Rugg & M. G. H. Coles (Eds.), *Electrophysiological studies* of *human cognitive function.* New York: Oxford University Press.

Pizzioli, F., & Schelstraete, M. A. (2007). Lexical decision task in children with specific language impairment. *Proceedings of the 31st Boston University Conference on Language Development.*

Polich, J. (1985). Semantic categorization and event-related potentials. *Brain and Language, 26,* 304-321.

Porpodas, C. D. (1999). Patterns of phonological and memory processing in beginning readers and spellers of Greek. *Journal of Learning Disabilities, 32*, 406–416.

Sela, I., Horowitz-Kraus, T., Izzetoglu, M., Shewokis, P. A., Izzetoglu, K., Onaral, B., and Breznitz, Z. (2011). Brain Activity of Young and Adult Hebrew Speakers during Lexical Decision Task: fNIR Application to Language. *Foundations of Augmented Cognition. Directing the Future of Adaptive Systems: Lecture Notes in Computer Science, 6780/2011*, 231-239.

Singhi, P., Kumar, M., Malhi, P., & Kumar, R. (2007). Utility of the WHO Ten Questions Screen for disability Detection in a Rural Community- the North Indian Experience. *Journal of Tropical Pediatrics, 53(6),* 383-387

Siok, W. T., & Fletcher, P. (2001). The role of phonological awareness and visual orthographic skills in Chinese reading acquisition. *Developmental Psychology, 37,* 886–899.

Swaab, T., Brown, C., & Hagoort, P. (2003). Understanding words in sentence contexts: The time course of ambiguity resolution. *Brain and Language, 86,* 326-343.

Taroyan, N. A. and Nicolson, R. I. (2009). Reading words and pseudowords Dyslexia: ERP and behavioural tests in English speaking adolescents. *International Journal of Psychophysiology, 74,* 199-208.

MEASUREMENT OF REACTION TIME FOR PROCESSING OF CONCRETE AND ABSTRACT WORDS

[1]Sampath Kumar Lagishetti, & [2]Goswami S. P.

Abstract

Concreteness is a phenomenon which refers to the linguistic stimuli to indicate concrete concepts generally show an advantage over abstract concepts. Dual-coding theory is a classical explanation for concreteness effect (Paivio, 1971, 1986). The aim of the study was to measure the reaction time (Judgment task) in processing abstract and concrete words and to find out the gender differences if any. Twenty young adults within the age range of 18-25years (10 males and 10 females) were considered in this study. Stimuli used were abstract and concrete words and total of 100 words were taken from various resources and was given for rating to twenty speech language pathologist and asked them to rate on 3 point rating scale. Out of which 50 words in each category were considered for experiment. Stimuli were audio recorded by a native Kannada adult female speaker and the recorded stimuli were normalized. Separate program was done loaded in DMDX and the stimulus was presented through Headphones and all the participants were asked to judge the type of word. Mixed analysis of variance repeated measures analysis of variance was done for comparison between abstract and concrete words and gender differences. The results of the present study revealed that there were faster reaction times for concrete words compared to abstract words and no gender differences were observed. Conclusion of the study explains that concreteness is an important variable in differentiating the processing abstract and concrete words.

Key words: *Dual coding theory, Neuro typical, Stimuli, Behavior, Response*

Concreteness effect is a phenomenon that has been broadly reported in the memory and verbal learning literature. It refers to the ability of the linguistic stimuli to indicate concrete concepts which e.g., “book” generally show a performance advantage over abstract concepts e.g., “sad” (Tolentino, & Tokowicz, 2009). This finding has been demonstrated in a variety of tasks including lexical decision (James, 1975; Schwanenflugel, & Shoben, 1983). The term concreteness effect refers to the observation that concrete nouns are processed faster and more accurately than abstract nouns in a variety of cognitive tasks (Jessen, Heun, Erb, Granath, Klose, Papassotiropoulos, & Grodd, 2000).

The classical explanation for the concreteness effect comes from Paivio’s (1971 & 1986) dual coding theory which states that there are systems for functionally and structurally distinct representational systems, an imagery system specific for the depiction and processing of nonverbal stimuli, and verbal system specific for the handling of linguistic stimuli. According to this theory, a variant of the several semantic-systems views- verbal “linguist” semantic system and a nonverbal “imagistic” semantic system were associated and responsible in processing of concrete words, whereas the linguistic system is responsible for abstract words. Concrete words have advantages over abstract words as they are linked with information stored in both systems. For example, participants are able to recognize “book” faster compared to “sad” in a lexical decision task because “book” is processed and represented in both linguistic and imagistic systems while “sad” is processed and represented only in the linguistic system.

Processing of concrete and abstract words is yet unaddressed issue in the current literature in both Neuro typical adults and adult language disorders. In treatment of persons with aphasia, concrete words have more effect on treatment as concrete words have both imagery and verbal systems information where as abstract words have only verbal system. Persons with aphasia were hypothesized to utilize the right hemisphere for semantic processing instead of the damaged left hemisphere (Kiran, & Tuchtenhagen, 2005). If concrete words are processed bilaterally, then persons with aphasia will show preference for concrete words, which will be shown in a treatment study using abstract and concrete concepts. This processing of abstract and concrete words were mainly studied using two kinds of methods those are behavioral measurements and electrophysiological measurements.

[1]Junior Research Fellow, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: lagishettisk@gmail.com & [2]Professor in Speech Pathology, AIISH, Mysore-06, Email: goswami16@yahoo.com

Behavioral measurements

Behavioural testing is based on a participant's response, in which participants have to respond to stimuli either verbally or through other means of responding like pressing the button. In this behavioural measurement participants cooperation, interest and attention towards the stimuli can affect the response pattern.

James (1975) carried out four different experiments on 48 undergraduates, where they were asked to judge the presented letter strings were either words or non-words. Results of the study revealed that faster reaction time for concrete words than for low frequency abstract words when nonword distracters were pronounceable. However there was no effect of concreteness on for high-frequency nouns. These results indicate that lexical decision involves repossession of semantic information in certain conditions.

Three experiments done by Kroll, Judith, Merves, and Jill (1986) on 48 undergraduates in which they compared the speed and accuracy of lexical decisions for concrete and abstract nouns. In one of their experiment they found that concrete nouns had small speed advantage in lexical decision than abstract words. Other studies show that more active consistent representations for concrete words than abstract words (Van Hell & De Groot, 1988a, and 1998b). Behavioral performance from another study confirms the previously established finding that concrete words are recognized more quickly and accurately than abstract words (Kiehl, Liddle, Smith, Mendrek, Forster & Hare, 1999). Schwanenflugel and Stowe (1989) studied the influence of a sentence context on the processing of abstract and concrete words on 38 native English speaking students and the results supported a context availability view that abstract words were comprehended more slowly than concrete words.

Neural basis for concreteness effect was studied basically using behavioral methods. The results using behavioral methods showed that in both implicit and explicit memory tests there was an obvious concreteness effect was observed and faster reaction for concrete words compared to abstract words. Results suggested that due to contextual information advantage of concreteness for concrete words was more in comparison to abstract words (Xiao, Zhao, Zhang, & Guo, 2011).

In behavioral measurements, judgment (yes or no) and reaction time were the response criteria used in the literature for understanding in semantic processing and category judgment. Studies have found that for processing of abstract words needs more reaction time compared to the concrete words.

Electrophysiological measurements

Electrophysiological test measures are used to assess event related potentials in the brain. Event related potentials (ERPs) measures the brain activity by using scalp electrodes in non-invasive method during cognitive processing. Kounios and Holcomb (1994) examined the effect of concreteness and concreteness judgment tasks using lexical decision task on event related potentials (ERPs) and a repetition- priming paradigm respectively. More negative ERPs were elicited for concrete words between 300 and 500 milliseconds after stimulus onset than abstract words.

West and Holcomb (2000) performed sentence verification tasks in which the final word of each sentence was either concrete or abstract on three groups of participants. For each group the truthfulness judgment involved three characteristics these were image generation, semantic decision and evaluation of surface. In three groups there was a variation in magnitude of concreteness effect and for participants in the imagery and semantic groups, this effect was significant. There was a widespread and extended N400 which was sensitive to concreteness observed in both the imagery and semantic conditions. Finally the results of this study supported the dual coding hypothesis.

Study done on sixteen students using event related potentials in which sentences ending with congruent (abstract and concrete) words and anomalous words (Holcomb, Kounios, Anderson, & West, 1999). They found that more negative ERPs were elicited for concrete final words than abstract final words. These results have shown that there were also clear effects of concreteness; this finding further provides corroborative support to the argument that the observed effects of concreteness.

Event related potentials (ERPs) were recorded on 23 right-handed participants using 119 scalp electrodes in lexical decision task. The present examined relationship between word concreteness and word frequency using ERP measurements during a lexical decision task. The results showed that more negative ERPs for concrete nouns than abstract nouns at 200-300 and 300-500ms after stimulus onset, regardless of word frequency (Zhang, Guo, Ding, & Wang, 2006).

Studies done on semantic judgment for processing of abstract and concrete words through behavioral measurements showed that longer reaction for abstract words compared to concrete words. In electrophysiological measurements, event related potentials have been considered as response criteria in the literature. An electrophysiological findings suggests that more negative for ERPs and widespread of N400 for concrete words compared to abstract words. Thus, suggests that concreteness effect plays a role in processing abstract and concrete words and which is in Constance with dual coding theory. An issue yet unaddressed in the current literature is the processing of abstract and concrete nouns in normal healthy adults and adult language disorders. Ethno- cultural differences exist in older adults within the framework of aging and neurogenic language disorders (Payne 1997). Hence, there is a need to study the processing of different types of words and more over there is a less literature in Indian scenario. Thus, the present study aims for the judgment task using reaction time as measure for processing abstract and concrete words.

Method

Participants

A total of 20 young adults in the age range from 18 to 25 years were included in the study. In that 10 were male and, 10 were females.

The participants were selected based on the following criteria:

- All the participants were native speakers of Kannada language
- None of the participants had any history of significant current or past hearing difficulties, or any history of neurological diseases.

Table 1. *Number of participants in the study*

Participants	Gender	No. of participants
Neuro typical adults	Male	10
	Female	10
	Total	20

Instrument and Stimuli

DMDX is software which was basically developed for behavioral psychology experiments for measuring reaction times (Kenneth, & Jonathan, 2003). There are two separate programs which have to be run before doing any experiment using DMDX. The first software is called TimeDx which confirms the refresh rate and other parameters on the screen of the monitor for displaying audio or video files. This refresh rate varies across different computers and models. DMDX software works only after running the TimeDx module. In this study, one separate program was done which was loaded on personal computer while carrying out the experiment.

Stimuli of the present study were abstract and concrete words, in which abstract words refer to words where they have no physical referents and concrete words refer to objects or events that are available to the senses. Hundred words were taken in each group from various resources. Further, these words were rated on a 3-point rating scale for familiarity among 20 speech language pathologists (native Kannada speakers). In this rating scale, '0' indicates abstract word (e.g. happy) and '2' indicates the concrete word (e.g. book). The 50 abstract and 50 concrete words were considered for the present study. The speech language pathologists were instructed as follows:

"The purpose of this study is to find out how well each of the following items represents abstract and concrete words. Your task is to rate how good an example of each item in a scale ranging from 0-2. A rating of 0 means you feel the item is Abstract word (e.g. happy), and 1 means you feel the item cannot be differentiated whether it is abstract or concrete word. A rating 2 means, you feel that the item is a very good example of concrete word (e.g. book)." The prepared stimuli were audio recorded in a sound treated room by a Native Kannada adult female speaker. The recording was done on a personal computer using a unidirectional microphone, kept at a distance of 10 cm from the speaker's mouth by using Adobe Audition (3.0), with a resolution of 32-bits and a sampling rate of 44.1 kHz. The recorded stimulus was normalized so that all the test items have the same intensity.

Procedure

The participants were seated in a comfortable position facing the screen of the laptop in a quiet room. A series of words were presented randomly to the participants through head phones (auditory mode). Creative head phones HS-390 were used for auditory stimulus. The participant has to press the button '1' in key pad, if the stimulus is concrete word and the participant has to press the button '0' if the stimulus is abstract word. The inter stimulus interval was 2500millisec. If the participant does not respond within the given duration the DMDX software will consider it as no response. The procedure and duration of the study was explained to the participant. Prior written consent was taken from the participant for participating in the study. Reaction time was collected for all the Kannada stimuli (Abstract vs. Concrete words). For the analysis, the reaction time was compared between abstract and concrete words and the gender differences also were compared.

Results and Discussion

The main objective of the current study was to observe the differences in the processing of concrete and abstract words in Neuro typical adults using a reaction time as a measure and to find the gender differences if any.

Table 2 summarizes the data. It explains the average reaction times for both concrete and abstract words. Average reaction time for males and females for concrete words were 391.9475 and 394.6587 respectively; for abstract words mean reaction time in males and females were 573.6538 and 578.5500 respectively. The average reaction time in total (combination of males and females) for abstract and concrete words was 393.3031 and 576.1019 respectively. There was 183msec faster reaction time for concrete words than abstract words were observed in total.

Table 2: *Mean and standard deviations of reaction time for concrete and abstract words*.

Stimulus	Gender	Mean	Std. deviation
Concrete words	Male	391.9	31.9
	Female	394.6	34.6
	Total	393.3	32.2
Abstract words	Male	573.6	23.5
	Female	578.5	19.9
	Total	576.1	21.2

Mixed ANOVA (Analysis of variance) repeated measures ANOVA for comparison of words (concrete & abstract words) with gender as independent factor.

Mixed ANOVA (Analysis of variance) repeated measures ANOVA for comparison of words (concrete & abstract words) revealed a main effect for words (concrete & abstract words) ($F= 695.412$, $P<0.0001$) and for gender ($F= 0.096$, $P>0.05$) indicating that was a statistically significant difference in the processing of concrete and abstract words and there was no statistically significance difference found across gender. There was no interaction between words and gender ($F= 0.025$, $P>0.05$). Figure 1 displays the means of the reaction times for concrete and abstract words for male and female. In which, X- axis represents gender and Y- axis represents the time in milliseconds.

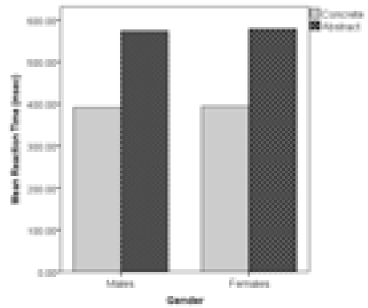

Figure 1: *Mean reaction times for concrete and abstract words obtained by male and female participants.*

The reaction time was measured for all participants and the results reveal that there is a faster reaction time for concrete words compared to abstract words and there was no gender differences were noticed These results are consistent with the dual coding theory which explains that concrete words have different processing advantages over abstract words because they have admittance to information from multiple systems and concreteness effect refers to the observation that concrete nouns are processed faster and more accurately than abstract nouns in a mixture of cognitive tasks.

This pattern is also consistent with previous studies. In the literature it has been shown that the reaction times for concrete words are faster than the abstract words. Three experiments done by Kroll, Judith, Merves, and Jill (1986). In one of their experiment they found that concrete nouns had small speed advantage in lexical decision than abstract words. In other study the results shows that concrete words are recognized more quickly and accurately than abstract words (Kiehl, Liddle, Smith, Mendrek, Forster & Hare, 1999). In literature it has been shown that there were more active consistent representations for concrete words than abstract words (Van Hell & De Groot, 1988a, and 1998b).

The present study results are also consistent with other studies which show that abstract words were comprehended more slowly than concrete words on context availability (Schwanenflugel & Stowe, 1989). It suggests that due to contextual information advantage of concreteness for concrete words was more in comparison to abstract words (Xiao, Zhao, Zhang, & Guo, 2011). In other electrophysiological studies explains that there was a more negativity of event related potential (300 to 500milliseconds) which is in consistent with dual coding theory (Kounios & Holcomb, 1994; West & Holcomb, 2000). Hence, it suggests that the concreteness is an important variable in processing concrete and abstract words.

Conclusions

The present study was conducted to compare the reaction time for processing abstract and concrete words using judgment task. The current study provided data on processing of concrete and abstract words in Neuro typical adults in the age range of 18-25 years. There are systems for functionally and structurally distinct representational systems, an imagery system specific for the depiction and processing of nonverbal stimuli, and verbal system specific for the handling of linguistic stimuli which was explained in dual coding theory (Paivio, 1971; 1986). Imagery processes may occur faster than other processes. (Van Schie, Wijers, Mars, Benjamina, & Stowe, 2005), it is expected that in some aspects larger concreteness differences can be observed than others. The processing differences between concrete and abstract words can be clearly revealed by studied comparing word processing in different stages. The results of the present study shows that the reaction times were faster for concrete words than compared to abstract words and there were no gender differences were observed. The overall conclusion for this study explains that the concreteness will have effect in processing the concrete words than compared to abstract words. Future studies needed that employ larger sample size and further studies can be carried out to address the processing of abstract and concrete words in language disorders.

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References

Holcomb, P. J., Kounios, J., Anderson, J. E., & West. (1999). Dual-coding, context-availability, and concreteness effects in sentence comprehension: An electrophysiological investigation. Journal of Experimental Psychology: Learning, Memory & Cognition, 25, 721-742.

James, C. T. (1975). The role of semantic information in lexical decisions. *Journal of Experimental Psychology: Human perception and performance, 104*, 130-136.

Jessen, F., Heun, R., Erb, M., Granath, D.O., Klose, U., Papassotiropoulos, A., & Grodd, W. (2000). The concreteness effect: evidence for dual coding and context availability. *Brain and Language, 74*(1), 103-112.

Kenneth, T. F., & Jonathan, C. F. (2003). DMDX: A window display program with millisecond accuracy. *Behavioral Research Methods, 35*, 116-124.

Kiehl, K. A., Liddle, P. F., Smith, A. M., Mendrek, A., Forster, B. B., & Hare, R. D. (1999). Neural pathways involved in Processing of concrete and abstract words. *Human Brian Mapping, 7*, 225-233.

Kiran, S., & Tuchtenhagen, J. (2005). Imageability effects in normal Spanish-English bilingual adults and in aphasia: Evidence from naming to definition and semantic priming tasks. Aphasiology, 1-15.

Kounios, J., & Holcomb, P. J. (1994). Concreteness effect in semantic processing: ERP evidence supporting dual-coding theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*, 804-823.

Kroll. Judith, F., Merves., & Jill S.(1986). Lexical access for concrete and abstract words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*(1), 92-107.

Paivio, A. (1971*). Imagery and verbal process*. New York: Holt, Rinehart & Winston.

Paivio, A. (1986*). Mental representations: A dual coding approach*. New York: Oxford University Press.

Payne, J. C (1997). *Adult neurogenic language disorders: assessment and treatment: a comparative ethno biological approach*. London: Singular publishing group, inc.

Schwanenflugel, P. J., & Shoben, E. J. (1983). Differential context effects in the comprehension of abstract and concrete verbal materials. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*, 82-102.

Schwanenflugel, P. J., & Stowe, R. W. (1989). Context availability and the processing of abstract and concrete words in sentences. *Reading Research Quarterly, 24*(1), 114-126.

Tolentino, L. C., & Tokowicz, N. (2009). Are pumpkins better than heaven? An ERP investigation of order effects in the concrete-word advantage. *Brain and Language, 110*, 12-22.

Van Hell, J. G., & De Groot, A. M. B. (1998a). Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association. *Bilingualism: Language and Cognition, 1*, 193-211.

Van Hell, J. G., & De Groot, A. M. B. (1998b). Disentangling context availability and concreteness in lexical decision and word translation. *Quarterly Journal of Experimental Psychology, 51A*, 41-63.

Van Schie, H. T., Wijers, A. A., Mars, R. B., Benjamina, J. S., & Stowe, L. (2005). Processing of visual semantic information to concrete words: Temporal dynamics and neural mechanisms indicated by event – related brain potentials. *Cognitive Neuropsychology, 22*, 364-386.

West, W. C., & Holcomb, P. J. (2000) Imaginal, semantic, and surface- level processing of concrete and abstract words: An electrophysiological investigation. *Journal of Cognitive Neuroscience, 12*(6), 1024-1037.

Xiao, X., Zhao, D., Zhang, Q., & Guo, C. Y. (2011). Retrieval of concrete words involves more contextual information than abstract words: Multiple components for the concreteness effect. *Brain and Language, 29*, In Press.

Zhang, Q., Guo, C-Y., Ding, J-H., & Wang, Z-Y. (2006). Concreteness effects in the processing of Chinese words. *Brain and Language, 96*, 59-68.

Appendix

Abstract words		Concrete words	
beːga	aːlo tʃane	oɳɖe	bekku
aːtura	viʃrantI	kIvI	naːjI
tʃInte	vIraːma	mannu	aːne
dʒ iːvana	aː krama	tuppa	koːtI
kahI	avakaː ʃa	tʃandra	IlI
koːpa	sandarb^{h}a	baːjI	handI
noːvu	apaːja	kurI	daːra
IrJ tje	tondare	haɖagu	haːvU
gʌvrava	prajatna	suːrja	hullI
manavijate	kʃamIsu	naːlIge	kIʈakI
pritI	tappu	niːru	suːdʒI
atmavan tʃane	uːhe	baːla	kolI
marjade	baravase	haːtI	kere
truptI	avamaːna	mara	man tʃa
dveʃa	krupe	dana	ɖabbI
bramme	adrusʈa	tʃaːku	kaːgɛ
niʂʈe	art^{h}a	kallu	b^{h}aːvI
vidʒ aja	duk^{h}a	tʃ^{h}atri	tʃaːpe
guna	aːtma	haklI	samudra
d^{h}aIrja	nIjattu	gIɖI	bangaːra
njaja	suk^{h}a	huːvu	noɳa
kanasu	santoʃa	tantI	tʃaːma
nambike	nemmadI	hasige	meː dʒu
gnana	e tʃ tʃarIke	pustaka	pennu
svatantra	ʃantI	kannaɖI	ba tʃalge

PARAGRAPH COMPREHENSION DEFICITS IN HINDI SPEAKING PERSONS WITH APHASIA IN DIFFERENT MODALITIES: A PRELIMINARY STUDY

[1]Santosh Kumar, & [2]Goswami S.P.

Abstract

The study was carried out with the aim of developing a paragraph comprehension test in Hindi language for persons with aphasia in auditory and orthographic mode. The developed paragraph consisted of having five questions to evaluate paragraph comprehension in auditory and orthographic mode. The material was administered on 60 neuro-typical adults and 12 persons with aphasia aged 18-65 years. It was observed that there was a significant difference between the mean scores of neuro-typical adults and persons with aphasia. Based on this finding it is recommended that the developed material can be used to assess paragraph comprehension in persons with aphasia in auditory and orthographic mode.

Key words: *Neuro-typical, Hindi, Assessment.*

Aphasia is an acquired disorder of language in adults due to damage in the brain, most commonly caused by cerebrovascular accident (CVA) in the left side of the brain. Aphasia impairs a person's ability to comprehend and produce spoken and written language. Aphasia disrupts the symbolic systems of speaking, listening, reading, and writing (McNeil, 1983; Chapey & Hallowell, 2001; LaPointe, 2005).

Comprehension deficits of the spoken and written language are variable and involve multiple processes (Brookshire, 1974; Duffy & Coehlo, 2001). Researchers also suggest that the processes required for comprehension of words and sentences differ from the processes employed for comprehension of discourse. A review of the literature revealed a positive correlation between linguistic, extra-linguistic (visuographic) context, and improved auditory comprehension by persons with aphasia (Stachowiak, Huber, Poeck, & Kerchensteiner, 1977; Waller & Darley, 1978; Pierce & Beekman, 1985; Brookshire, 1987; Pierce, 1983; 1988; 1991; Duffy & Coelho, 2001).

Brookshire and Nicholas (1984) studied paragraph comprehension in persons with aphasia, persons with right hemisphere damaged, and persons with non-brain damaged. The participants were asked to pay attention to brief narrative paragraphs that contained four focal ideas with details that were related to those central ideas. Subsequent to listening to the narratives the participants were administered tests on comprehension and retention of the focal ideas and its adjunct details. The results of the test revealed that the participants were able to recall the focal ideas than the adjunct details presented in the paragraph. The scores for the comprehension of paragraphs for persons with non-fluent aphasia and persons with right hemisphere damaged were not significantly dissimilar from the scores obtained by persons with non-brain damaged. The results obtained on the performance for comprehension of paragraph from persons with fluent and mixed aphasia were significantly lower than the scores obtained for persons with non-brain damaged and persons with right-hemisphere damaged.

Stachowiak, Huber, Poeck, and Kerchensteiner (1977) studied the impact of linguistic context on auditory comprehension. The researchers examined three hypotheses relative to the effect of contextual information on auditory comprehension: (a) persons with aphasia have an impaired ability to utilize context for comprehension, (b) linguistic deficits compromise contextual comprehension skills, and (c) persons with aphasia can utilize verbal and contextual information to fill in linguistic related deficits. The researcher read short passages to the participants. The participants have to select the picture from a multiple choice picture set of five line drawings that fit the story to the best. The three pictures included semantic foils, a picture depicting the main idea of the story, and one showing the literal sense of a metaphorical comment used in the story. The results revealed that the persons with aphasia performed similarly to both groups of control participants on the passage listening task. Waller and Darley (1978) reported that the brief presentation of context to the participants prior to the administration of the test improved their performances. Pierce and Beekman (1985)

[1]Junior Research Fellow, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: santoshaslp@gmail.com & [2]Professor in Speech Pathology, AIISH, Mysore-06, Email: goswami16@yahoo.com

demonstrated that the auditory comprehension of syntactically and semantically complex sentences by persons with aphasia may be increased when provided extra-linguistic, visuographic, or context. The researchers presented target sentences to participants in three different experimental conditions: (a) in isolation, (b) following a picture that depicted the sentence, and (c) after a semantically related sentence. Results revealed an interaction between comprehension severity (high-level or low-level), sentence type (simple actives, reversible passives, and reversible actives), and contextual condition (linguistic or visuographic). Participants with low level comprehension skills demonstrated improved auditory comprehension both in the linguistic and visuographic conditions. However, statistical analyses revealed no significant differences between the two types of context.

The literature reveals a sequence of studies that disclose the positive impact of context on the auditory comprehension of persons with aphasia. However, there is limited research regarding the impact of linguistic and visuographic context on reading comprehension by persons with aphasia (Germani & Pierce, 1992; Smith, 2005).

Germani and Pierce (1992) studied the influence of linguistic context on the reading comprehension of persons with aphasia. Participants silently read three types of narratives: (a) predictive narratives, (b) non-predictive narratives, and (c) predictive narratives without target sentences. All stimuli were presented in enlarged type on 8x11-inch cards. After reading the narrative, the participants turned to the next page to find the related question. Participants pointed to the correct noun choice, from a field of two, without referring back to the narrative. Results revealed that 75% of the participants benefited from the predictive narratives and 83% of the participants benefited from the non-predictive narratives.

Familiar topics and contents can be domain knowledge, which individuals know something about the material they hear or read. Research on persons with neuro-typical demonstrates that persons having prior knowledge about the paragraph perform better than the persons having no prior knowledge about the paragraph. The study conducted by Hambrick and Engle, 2002; Miller, 2001; Van Overschelde and Healy, 2001, used test stimuli that incorporated familiar topics and created a high domain familiar knowledge.
Researchers have shown that context improves persons with aphasias auditory comprehension. Semantic constraints, semantic plausibility, predictive and non-predictive information, and familiar topics are the specific contextual information which helps in comprehension of paragraph. Jones, Pierce, Mahoney, and Smeach (2007) studied the influence of familiar content on comprehension in persons with aphasia. They included eleven persons with aphasia and eleven persons without brain damage in their study. All the participants listened to short paragraphs that differed in the presentation of the familiar context. In half of the paragraph the people and places remained generic and unknown to the participants while the other half were familiar to the participants. Questions were asked to the participants related to both. Results revealed that the participants answered the questions more correctly when content were known than with unknown content. Results reinforced the premise put forth by them and did not relate to age, education, time-post-onset, or comprehension and naming skills. Thus, the study proved that familiar content could be considered as a type of context that enhances comprehension skills in persons with aphasia. Several tests are available for paragraph comprehension evaluation tools such as the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1972), Reading Comprehension Battery for Aphasia (LaPointe & Horner, 1979), and Western Aphasia Battery (WAB) (Kertesz, 1979).

The first edition of Boston Diagnostic Aphasia Examination (BDAE) was published by Goodglass and Kaplan in 1972. The BDAE-3 (Goodglass & Kaplan, 2001) has three versions: standard, short, and extended. BDAE-3 short form takes less administration time. The extended version of BDAE-3 provides an extensive examination than the standard version. The standard BDAE-3 is divided into five language related sections. These are conversational and expository speech, auditory comprehension, oral expression, reading and writing. The extended version includes a sixth section: praxis. The performance of the person is rated on a seven point rating scale. This test predicts progress in therapy (Davidoff & Katz, 1985; Helm-Estabrooks, & Ramsberger, 1986). BDAE is more useful for assessments during detailed studies of aphasia and aphasia rehabilitation. Reading includes basic symbol recognition (letters and numbers), word recognition (picture-word matching and lexical decisions), phonics (basic homophone matching and advanced phonic analysis), derivational and grammatical morphology, oral reading (basic words, sentence reading and comprehension, and paragraph reading and comprehension). Comprehension responses are based on a multiple-choice format. The BDAE auditory comprehension subtest was not an adequate predictor of auditory paragraph comprehension in independent standardized material (Brookshire & Nicholas, 1984).

The first edition of Reading Comprehension Battery for Aphasia (RCBA) was developed by LaPointe and Horner, 1979 and revised RCBA-2 by LaPointe and Horner, 1999. The RCBA-2 is designed to provide systematic evaluation of the nature and degree of reading impairment in adolescents and adults with aphasia. The test is described by authors as a criterion referenced measure with no normative basis. It takes about one hour to administer the test. The test includes ten core subtests, each one containing ten tests items, and seven supplemental subtests of variable lengths. Core subtests include measures of single word comprehension, functional reading of short passages, synonyms, sentence and paragraph length comprehension, and syntax. Supplementary tasks examine single letter recognition, identification of real versus nonsense consonant-vowel-consonant trigrams, and oral reading of words and sentences. Items are scored on being correct or incorrect and the time to complete each subtest is recorded. Flanagan and Jackson (1997) examined test-retest reliability of the original RCBA in a small sample of non-brain-damaged adults and reported reasonable levels of reliability. A study checked for the aphasic performances on the original RCBA which examined aphasia treatment modalities (Wertz, Weiss, Aten, Brookshire, Garcia-Bunuel, Holland, et al., 1986).

The Western Aphasia Battery (WAB) was designed to evaluate the main clinical aspect of language function in person with aphasia. This test classifies aphasia sub-types and rates the severity of the aphasic impairment. The test is designed for both clinical and research use. Aphasia quotient (AQ) is determined by the performance on spontaneous speech, auditory comprehension, repetition, and naming. The performance quotient (PQ) is determined by the performance on the reading and writing, praxis, construction, and Raven's Colored Progressive Matrices. Cortical quotient (CQ) is determined by adding the AQ and the PQ. Language quotient (LQ) is the most recent score developed for this test (Shewan & Kertesz, 1984). The LQ is a composite of all language sections, including reading and writing. The revised version of this test is Western Aphasia Battery-Revised (WAB-R; Kertesz, 2006). It assesses both linguistic and non-linguistic skills. It also includes bedside evaluation which provides a quick look at the person's functioning. There are some Indian versions of WAB i.e. WAB- Hindi (Karanth, 1980), WAB- Kannada (Shymala & Vijayashree, 2008), and WAB-Telugu (Sripallavi & Shyamala, 2010). Study by Nicholas, MacLennan, and Brookshire (1986) reported that both persons with aphasia and neuro-typical participants were able to answer a similar number of questions about a paragraph without reading the passage. This is suggesting a high passage dependency of this test. This dependency applied to both test i.e. BDAE and WAB.

As reviewed above, the quoted tests vastly cover all the domains with not much emphasis towards assessment of paragraph comprehension across modes. This is more so in the Indian context. Hence, the need to develop a paragraph comprehension test for persons with aphasia was realised and Hindi was the chosen language.

The objectives of the study were development of the paragraph test in Hindi and administration of the test on neuro-typical and persons with aphasia

Method

Procedure

The present study was carried out in two phases. First phase included development of the passage; in the second phase, the passage was administered on neuro-typical adults and persons with aphasia.

Phase- I: Development and Description of Test Material*: Preparation of stimuli*

The first phase involved the development of the test material. Three passages were selected on the basis of the linguistic background of the target population. Twenty Speech Language Pathologists (SLPs), who were proficient in speaking, reading, and writing Hindi language and who had at least two years of clinical experience, were asked to rate the passages for assessing paragraph comprehension in persons with aphasia. A three point rating scale was applied to rate the stimuli on the basis of inappropriate, appropriate and most appropriate (in terms of familiar) by the SLPs. For the final set of test, 95% appropriate passage as rated by the SLPs was selected.

The finalized passage consists of 176 words with five questions. The passage was presented in auditory and orthographic mode separately. Researchers have used their own voices for the auditory mode presentation and kept the written sentences in front of the participants for orthographic mode presentation. The answer set included multiple-choice answers that included one correct answer and three foils. For the response, the person had to point to the correct answer. Scoring pattern followed a three point rating scale as described in the following Table 1.

Table 1: *Scoring pattern.*

Score	Response
2	Correct
1	Correct with prompt
0	Incorrect even with prompt

Feedback about test

The test was given for feedback rating to 22 SLPs, who were native speakers of Hindi with at least three years of clinical experience. The SLPs were asked to judge the passage based on feedback rating questionnaire adopted from “Feedback Questionnaire for Aphasia Treatment Manuals” (Field Testing of Manual for Adult Non-fluent Aphasia Therapy in Kannada, MANAT-K; Goswami, Shanbal, Samasthitha, & Navitha, 2010) (Table 2). The feedback rating questionnaire required the rater to judge the passage on various parameters such as simplicity, familiarity, complexity, iconicity, arrangement etc., while keeping in mind the abilities and performance of a person with aphasia.

Table 2: *Responses of the judges regarding the test material.*

Sl. No.		Very Poor	Poor	Fair	Good	Excellent
1	Simplicity				9	13
2	Familiarity				8	14
3	Presentation				8	14
4	Volume			3	10	9
5	Relevancy			1	7	14
6	Iconicity			0	11	11
7	Accessible			1	9	12
8	Flexibility			2	8	12
9	Trainability			1	11	10
10	Stimulability			0	9	13
11	Feasibility			1	9	12
12	Generalization			1	6	15
13	Scope of practice			1	8	13
14	Scoring Pattern				9	13
15	Publications, Outcomes and Developers (professional background)*	Yes			1	
		No			21	
Total				11	122	175
Total %				3.57	39.61	56.82

**The SLPs were asked to rate this parameter in terms of “Yes” or “No”*

Phase- II: Administration of the test: The neuro-typical participants between the age group of 18-65 years were tested to establish a baseline which was considered as normative for this test. The participants were seated comfortably in a quiet environment. The test materials were arranged according to the demands of the task and order of mode of administration of the test. The instructions to the participants were given verbally.

Participants

A total of 72 participated in the study. The participants were divided into two groups: Group- 1 consisted of neuro-typical adults (30 males and 30 females) and Group- 2 consisted of persons with aphasia (8 males and 4 females). Table 3 and Table 4 show the demographic details of the participants:

Table 3: *Details of the participants of the study.*

Participants	Age range	Male	Female
Neuro-typical adults	18-65	30	30
Persons with aphasia	18-65	8	4

Table 4: *Demographic Summary of persons with aphasia.*

Age (years)	Gender	Provisional Diagnosis	Time post Onset (months)	Education level
49	M	Global Aphasia	3	Graduate
65	M	Global Aphasia	5	Graduate
58	F	Global Aphasia	5	10+2
62	F	Global Aphasia	4	Graduate
42	M	Broca’s Aphasia	5	Graduate
48	M	Broca’s Aphasia	6	Dip. in electronic communication
43	F	Broca’s Aphasia	12	Graduate
57	M	Broca’s Aphasia	23	Graduate
65	M	Broca’s Aphasia	7	Graduate
65	M	Broca’s Aphasia	19	Graduate
55	F	Broca’s Aphasia	6	10+2
58	M	Wernicke’s Aphasia	36	Post-graduate

Inclusion criteria

Ethical standards and considerations was maintained and adhered to while selecting the participants for the study. The participants (or family members/care takers in case of persons with aphasia) were explained the purpose and procedure of the study and their written consent was acquired. They were selected based on the following inclusionary criteria. The age of the participants was between 18-65 years. They didn’t have any known history of pre-morbid neurological illness, psychological disorders, and significant sensory and/or cognitive deficits. All the participants under consideration were the native speakers of Hindi and had at least a high school education. Pre-morbidly, all participants were right handed. Mini-Mental State Exam (Folstein, Folstein & McHaugh, 1975) was administered on neuro-typical adults to rule out any cognitive-linguistic deficits. The participants had aphasia due to ischemic stroke diagnosed by a Neurologist/Physician and were at least three months post-stroke and medically stable. WAB was administered to know the type of aphasia.

Presentation of Stimuli

The researcher read the paragraph to the participants to check their auditory paragraph comprehension. After reading the paragraph, the researcher asked questions to the participants related to the paragraph. Participants had to respond to the questions by pointing on multiple choice answer sheet provided. For orthographic mode, the researcher kept the paragraph in front of the participants. Immediately following completion of the reading passage, the researcher removed the passage stimuli, provided the participants with a copy of the written comprehension question and multiple choices answer sheet. Prior to proceeding to the comprehension questions, the researcher verified whether the participants understood the passage or not, or required repetition. Next, the researcher presented the corresponding question set, one question at a time, and the participants had to point to target answers. Once the participant provided an answer, the researcher presented the subsequent question. If a participant did not respond or said, “I don’t know,” the researcher repeated the question set up.

Setting and time duration for test administration

The researcher conducted the sessions in a quiet room at the participants’ home. Only the researcher and the participant were present in the room during the session. They were seated beside each other in front of the table. The administration of the test was recorded on a digital video camera recorder (Sony Handycam, model no. DCR-SR88). The administration time of the test taken for neuro-typical participants was approximately 15 minutes and around 30 minutes for the persons with aphasia.

Data Analysis

The mean values for each group were calculated separately and the mean scores were compared between neuro-typical adults and the persons with aphasia groups across modes. Statistical analysis was done using SPSS software (Statistical Package for the Social Sciences package, version 18.0). The tabulated scores were used for obtaining the mean (M) and standard deviation (SD). The researcher used non-parametric statistics due to non-normal distribution of the data. Non-parametric measures ‘Mann- Whitney U-test’ was used to obtain the significant difference measures. This allowed determination of group differences on passage comprehension in auditory and orthographic mode between neuro-typical adults and persons with aphasia.

Results and Discussion

In the present study, an attempt has been made to develop a paragraph for assessing comprehension for persons with aphasia. The mean and standard deviation values as shown in Table 5 revealed that neuro-typical adults had better performance on paragraph comprehension than persons with aphasia in both auditory and orthographic modes.

Table 5: *Mean and SD values for paragraph comprehension for neuro-typical adults and persons with aphasia in auditory and orthographic modes.*

Section	Mode	Neuro Typical adults		Persons With Aphasia	
		Mean (%)	SD (%)	Mean (%)	SD (%)
Paragraph comprehension	Auditory	100.00	0.00	49.16	36.54
	Orthographic	100.00	0.00	48.33	39.50

Mann Whitney U test revealed that there was a significant difference in paragraph comprehension in auditory $|Z|= 8.38$, and orthographic modes $|Z|= 7.97$ between neuro-typical adults and persons with aphasia. However, inspection of individual reading comprehension response accuracy revealed variability within the aphasic group. Persons with global aphasia had performed poorly than the other types of aphasia. Persons with Broca’s aphasia had performed better than those with Wernicke’s aphasia and persons with global aphasia in both the auditory and orthographic modes. Persons with aphasia performed similarly in both auditory and orthographic modes.

The results of the current study state that persons with aphasia can answer more precisely when a paragraph includes familiar content. This endorses the earlier conclusion that persons with aphasia benefit from contextual information in the form of predictive information, redundant information, and familiar topics (Germani & Pierce, 1992; Jones, Pierce, Mahoney, & Smeach, 2007). Attention and the domain knowledge may be helpful effect for the familiar content. If the participants are aware about the contents of the paragraphs they could have found these paragraphs to be more fascinating (Hambrick & Engle, 2002; Miller, 2001; Van Overschelde & Healy, 2001).

Better performance of persons with aphasia in auditory comprehension than orthographic comprehension could be due to less taxing in auditory mode than the orthographic mode. This is supported by the study where improved attention has been shown to enhance auditory comprehension for persons with aphasia (Helm-Estabrooks & Albert, 2004; Murray, 2002). Persons with global aphasia performed very poor in both auditory and orthographic modes. It may be due to the less attention span. Persons with Wernicke's aphasia have comparatively poor comprehension than persons with Broca's aphasia (Kertesz & Hooper, 1982), may be because of that Persons with Wernicke's aphasia had performed poor on paragraph comprehension than persons with Broca's aphasia.

Persons with aphasia would have perceived orthographic context as helpful when paired with auditory reading passage. Persons with aphasia, however, did not reveal significantly improved reading comprehension in the pictures form only (Brennan, Worrall, & McKenna, 2005). Furthermore, persons with aphasia would have comprehended better when paragraph would have presented in all three modes auditory, picture, and orthographic together. Rose, Worrall, and McKenna (2003) who reported significantly superior confidence ratings reported by persons with chronic aphasia after reading health brochures that incorporated aphasia friendly principles (i.e., simple words and sentences, large print, large amounts of white space, and relevant pictures) than after reading traditionally formatted health brochures. These findings recommend that modification of the visuographic components of reading materials facilitates and enhance in the confidence of persons with aphasia to carry out reading tasks.

These findings mirror those of other researchers who concluded that persons with aphasia with reduced comprehension skills on standardized aphasia battery subtests improved in their auditory comprehension given supports in the form of linguistic and/or visuographic context (Garrett, 1993; Garrett & Huth, 2002; Lasker, Hux, Garrett, Moncrief, & Eischeid, 1997; Pierce & Beekman, 1985). These results supports the findings of other investigators suggesting pictures adversely affect the comprehension of persons with aphasia (Brennan, Worrall, & McKenna, 2005; Waller & Darley, 1978).

Qualitative analysis of the professionals' responses about the test

It is evident from the Table 2 that the 22 SLPs who rated the test based on a feedback questionnaire on overall parameters as 56.82% excellent, 39.61% good, and 3.57% fair. However, none of professional rated the test as poor and/or very poor. Also for the publications, outcomes and developers (professional background) domain, one professional reported that they were aware of the other material available which can be used for assessing paragraph comprehension, and 21 professionals stated that they were not aware of any other test available either in the western or Indian context. Therefore, the professionals view was that this test can be used for persons with aphasia.

Conclusions

The present study highlights the paragraph comprehension deficits in Hindi speaking persons with aphasia in different modalities. Result showed that there was a significant difference in the performance on paragraph comprehension between neuro-typical adults and persons with aphasia across all modalities. The neuro-typical adults exhibited significantly better comprehension as compared to the persons with aphasia in auditory and orthographic modes. Results underscore the fact that research should be orientated at development of language specific material in a multilingual country such as India, to cater to the needs of all the assessors within a broad work culture.

Limitations of the Study and Future Directions

The results of the study need to be interpreted with caution as number of the participants were less. Further, the reliability and validity of the stimuli were not taken up, which is one of the major drawbacks of this study. However, the results of the study do provide corroborative evidence for obvious paragraph comprehension deficits in persons with aphasia with varying degree in different modalities. This is preliminary stage of work and work is underway to include participants. As with most preliminary studies, several limitations warrant further discussion. These include participant recruitment and heterogeneity, and picture array. Examination of these limitations may reveal directions for future research on this topic.

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References

Brennan, A., Worrall, L., & McKenna, K. (2005). The relationship between specific features of aphasia-friendly written material and comprehension of written material for people with aphasia: An exploratory study. *Aphasiology, 19,* 693-711.

Brookeshire, R. H. & Nicholas, L. E. (1984). Comprehension of directly and indirectly stated main ideas and details in discourse by brain-damaged and non-brain-damaged listeners. *Brain and Language, 21*(1), 21-36.

Brookshire, R. H. (1974). Differences in responding to auditory materials among aphasic patients. *Acta Symbolica, 5,* 1-18.

Brookshire, R. H. (1987). Auditory language comprehension disorders in aphasia. *Topics in Language Disorders, 8,* 11-23.

Chapey, R., & Hallowell, B. (2001). Introduction to language intervention strategies in adult aphasia. In R. Chapey (Ed.), *Language Intervention strategies in aphasia and related neurogenic communication disorders* (4th ed., pp. 3-17). Baltimore, MD: Lippincott, Williams, and Wilkins.

Davidoff, M., & Katz, R. (1985). Automated telephone therapy for improving comprehension in aphasic adults. *Cognitive Rehabilitation, 3,* 26-28.

Duffy, J. R., & Coelho, C. A. (2001). Schuell's stimulation approach to rehabilitation. In R. Chapey (Ed.), *Language Intervention strategies in aphasia and related neurogenic communication disorders* (4th ed., pp. 341-382). Baltimore, MD: Lippincott, Williams, and Wilkins.

Flanagan, J. L., & Jackson, S. T. (1997). Test-retest reliability of three aphasia tests: Performance on non-brain-damaged older adults. *Journal of Communication Disorders, 30,* 33-42.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-Mental State": A practical method for grading the mental state for the clinician. *Journal of Psychiatric Research, 12,* 189-198.

Garrett, K. L. (1993). Changes in the conversational participation of individuals with severe aphasia given three types of partner support. *Dissertation Abstracts International, 54,* 5113.

Garrett, K. L., & Huth, C. (2002). The impact of graphic contextual information and instruction on the conversational behaviors of a person with severe aphasia. *Aphasiology, 16*, 523-536.

Germani, M. J., & Pierce, R. S. (1992). Contextual influences in reading comprehension in aphasia. *Brain and Language, 42,* 308-319.

Goodglass, H., & Kaplan, E. (1972). *The assessment of aphasia and related disorders*. Malvern, PA: Lea & Febiger.

Goodglass, H., & Kaplan, E. (2001). *The Assessment of Aphasia and Related Disorders* (3rd Ed.). Baltimore: Lippincott, Williams and Wilkins.

Goswami, S. P., Shanbal, J. C., Samasthitha, S., & Navitha, U. (2010). Feedback Questionnaire for Aphasia Treatment Manuals. *In Field Testing of Manual for Adult Non-fluent Aphasia Therapy in Kannada (MANAT-K).* A project under AIISH research fund submitted to All India Institute of Speech and Hearing, Mysore.

Hambrick, D., & Engle, R. (2002). Effects of domain knowledge, working memory capacity, and age on cognitive performance: An investigation of the knowledge-is-power hypothesis. *Cognitive Psychology, 44*, 339–387.

Helm-Estabrooks, N., & Albert, M. (2004). Manual of aphasia and aphasia therapy. Austin, TX: Pro-Ed.

Helm-Estabrooks, N., & Ramsberger, G. (1986). Treatment of agrammatism in long-term Broca's aphasia. *British journal of disorders of communication, 21*, 39-45.

Jones, D. K., Pierce, R. S., Mahoney, M., & Smeach, K. (2007). Effect of familiar content on paragraph comprehension in aphasia. *Aphasiology, 21*(12), 1218-1229.

Karanth, P. (1980). *Western Aphasia Battery in Hindi*. ICMR project, All India Institute of Speech and Hearing, Mysore.

Kertesz, A. (1979). *Aphasia & associated disorders: Taxonomy localization, recovery*. New York: Grune and Stratton.

Kertesz, A. (2006). *Western Aphasia Battery-Revised*. New York: Grune and Stratton.

Kertesz, A., & Hooper, P. (1982). Praxis and Language: The extent and variety of apraxia in aphasia. *Neuropsychologia, 20*(3), 275-286.

LaPointe, L. L. (2005). Foundations, adaptations, and accommodations, Aristos. In L. LaPointe (Ed.), *Aphasia and Related Neurogenic Language Disorders* (pp. 1-18). New York: Thieme Medical.

LaPointe, L. L., & Horner, J. (1979). *Reading Comprehension Battery for Aphasia.* Tegoid, OR: C.C. Publications.

LaPointe, L. L., & Horner, J. (1999). *Reading Comprehension Battery for Aphasia-2.* Austin, TX: Pro-Ed.

Lasker, J., Hux, K., Garrett, K., Moncrief, E., & Eischeid, T. (1997). Variations on the written choice communication strategy for individuals with severe aphasia. *AAC Augmentative and Alternative Communication, 13,* 108-116.

McNeil, M. (1983). Aphasia: Neurological considerations. *Topics in Language Disorders, 3,* 1-19.

Miller, L. (2001). The effects of real-world knowledge on text processing among older adults. *Aging Neuropsychology and Cognition, 8,* 137–148.

Murray, L. (2002). Attention deficits in aphasia: Presence, nature, assessment, and treatment. In L. Murray (Ed.), *Seminars in speech and language, 22* (pp. 107–116). New York: Thieme.

Nicholas, L. E., MacLennan, D. L., & Brookshire, R. H. (1986). Validity of multiple sentence reading of comprehension tests for aphasic adults.

Journal of Speech and Hearing Disorders, 51, 82-87.

Pierce, R. S. (1983). Decoding syntax during reading in aphasia. *Journal of Communication Disorders, 16,* 181-188.

Pierce, R. S. (1988). Influence of prior and subsequent context on comprehension in aphasia. *Aphasiology, 2,* 577-582.

Pierce, R. S. (1991). Contextual influences during comprehension in aphasia. *Aphasiology, 5,* 379-381.

Pierce, R. S., & Beekman, L. A. (1985). Effects of linguistic and extralinguistic context on semantic and syntactic processing in aphasia. *Journal of Speech and Hearing Research, 28,* 250-254.

Pierce, R. S., & Beekman, L. A. (1985). Effects of linguistic and extralinguistic context on semantic and syntactic processing in aphasia. *Journal of Speech and Hearing Research, 28,* 250-254.

Rose, T. A., Worrall, L. E., McKenna, K. T. (2003). The effectiveness of aphasia friendly principles for printed health education material for people with aphasia following stroke. *Aphasiology, 17,* 947-963.

Shewan, C. M., & Kertesz, A. (1984). Effects of speech and language treatment on recovery from aphasia. *Brain and Language, 23*, 272-299.

Shyamala, K. C. & Vijayashree (2008). *Standardization of Western Aphasia Battery-Kannada.* A project under AIISH research fund submitted to All India Institute of Speech and Hearing, Mysore.

Smith, C. E. (2005). A comparison of decontextualized and contextualized reading skills in persons with severe aphasia. *Masters Abstracts International, 43*, 2226.

Sripallavi, M. & Shyamala, K. C. (2010). *Development of Western Aphasia battery in Telugu.* Unpublished Master's dissertation, University of Mysore, Mysore.

Stachowiak, F., Huber, W., Poeck, K., & Kerchensteiner, M. (1977). Text comprehension in aphasia. *Brain and Language, 4,* 177-195.

Stachowiak, F., Huber, W., Poeck, K., & Kerchensteiner, M. (1977). Text comprehension in aphasia. *Brain and Language, 4,* 177-195.

Van Overschelde, J., & Healy, A. (2001). Learning of nondomain facts in high- and low-knowledge domains. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 1160–1171.

Waller, M., & Darley, F. (1978). The influence of context on auditory comprehension of paragraphs by aphasic subjects. *Journal of Speech and Hearing Research, 21,* 732-745.

Waller, M., & Darley, F. (1978). The influence of context on auditory comprehension of paragraphs by aphasic subjects. *Journal of Speech and Hearing Research, 21,* 732-745.

Wertz, R. T., Weiss, D. G., Aten, J. L., Brookshire, R. H., Garcia-Bunuel, L., Holland, A. L., et al., (1986). Comparison of clinic, home, and deferred language treatment for aphasia: A Veterans Administration cooperative study. *Archives of Neurology, 43,* 653-658.

PERCEPTUAL ADAPTATION TO NATURAL FAST AND TIME COMPRESSED SPEECH IN YOUNG INDIAN ADULTS

[1]George Nooromplakal, [2]Ganesh A.C. & [3]Subba Rao T. A.

Abstract

It is well known from the previous research that the listener's can perceptually adapt to time compressed speech in isolated conditions. The ability of the listener to perceptually adapt in background noise has not yet thoroughly investigated in Indian languages. The present study was aimed to investigate the perceptual adaptation to natural fast sentences before and after time compressed speech in the presence of noise in Kannada language. A total of 24 normal hearing adults participated in the present study within the age range from 20 to 30 years. All participants were divided into two groups with 12 individuals in each group.

The sequence for Group I was normal rate, natural fast sentences, time compressed sentences and the sequence for Group II was normal rate, time compressed sentences, natural fast sentences. In each condition 25 sentences were presented to both groups. The adaptation effect was calculated using reaction time and word accuracy measurements. Result of the present study shows adaptation of listeners to natural fast speech. Accuracy and reaction time responses clearly indicated that the participants in II group had the advantage of time compressed speech presented before natural fast speech due to availability of spectral information. This also confirms the view that auditory system adapts to the stimulus presented in a particular context over a period of time. Clinical implication is discussed in terms of training Cochlear Implant children and also adults with stroke in whom speech perception is a challenging task.

Key words: *Speech perception, Accuracy, Reaction time, adaptation effect, Cochlear Implant*

Speech perception refers to a process of extracting meaningful words from a constant, fast changing acoustic signal of speech. It is the process by which the sounds of language are heard, interpreted and understood (Alho, 2010). As adult listeners, perception of message from the speaker is quite effortless. However, the simplicity of everyday conversation masks the perceptual and cognitive complexities concerned in perceiving speech. Upon examination of the speech stimulus, it is obvious that this everyday skill demands a perceptual ability of the listener (Holt, 2008). The perception of acoustic/phonetic characteristics of speech varies as a function of speaker, rate of speech, prosody, and so forth. Human speech perception is flexible and thus rapid adaptation takes place whenever there is a change in the speaker, speech rate or speech conditions (Sebastian-Galles, Dupoux, Costa & Mehler, 2000).

Perceptual adaptation is where our brain adapts to the perception that it receives and is the means by which the brain accounts for the difference that the subject may witness. The actual estimation of varying speech rates of speakers in the daily listening conditions accounts for better speech perception skills and improved communication act. There are quite number studies supports that there is adaptation effect to time compressed speech, noise-vocoded speech, foreign-accented speech and synthetic speech (Bradlow & Bent, 2007). Time-compressed speech is a technique used, often in perceptual tasks, to make recorded speech enclose more words in a given time, yet still be comprehensible. Within a speech act, speakers repeatedly vary their speech rate (Miller, Grosjean & Lomanto, 1984). These variations result in variations of co articulation and assimilation (Browman & Goldstein, 1990; Byrd & Tan, 1996), deletion of segments (Ernestus, 2002; Koreman, 2006), reduced vowel durations (Lehiste, 1970; Max & Caruso, 1997) and reduction of unstressed vowels (Lisker, 1973). The consequences of these variations force the listeners to use a normalization process which involves short term automatic compensations (Green, Cook, & Crawford, 1994; Miller et al., 1984; Miller & Liberman, 1979). For effective speech processing, listeners must be able to adjust to extreme changes in speech rate rapidly. When variations in speech rate are minimal, as in natural speech, listeners can accomplish this task without apparent effort. However, for extremely fast rates, adaptation becomes considerably more

[1]Clinical Specialist, Advanced Bionics India Pvt Ltd, Email: georgethomas_n@yahoo.co.in, [2]Lecturer, Dr M.V. Shetty College of Speech and Hearing, (MVSCSH), Mangalore-15, Email: gani0017@gmail.com, & [3]Professor and Principal, Dr M.V. Shetty College of Speech and Hearing, Mangalore-15, Email: drtasr.slp@gmail.com

difficult. In some of the previous studies the adaptation effect to fast speech was calculated by manipulating the temporal aspects of the signal while preserving the spectral components (Golomb, Peelle & Wingfield, 2007; Pallier, Dupoux, & Galles, 1998)

Studies have shown that listeners can adapt up to 38% compressed speech (Dupoux & Green, 1997). Janse (2004) proved that the processing for natural fast sentences is more complex than the artificially time compressed speech. It may due to natural fast speech lack both spectral and temporal domains (Koreman, 2006; Wouters & Macon, 2002).

Natural fast sentences also possess coarticulatory features which make them complicated to perceive. Peelle and Wingfield (2005) demonstrated that perceptual learning is comparable in young and older adults but maintenance and transfer of this learning decline with age. Time-compressed speech has a temporal and a segmental processing advantage over naturally produced fast speech (Janse, 2004). Studies suggest that listeners adapted to one type of fast speech facilitate adaptation and/or general performance for the other type (Adank & Janse, 2009).

Hence perception of natural fast speech is a complex task which the listeners achieve with compensatory processes. Perception to natural fast speech can also be achieved by training the listener with artificially time compressed speech which possesses fluctuations in temporal aspects and allows auditory system to get adapted to the temporal variations.

Even though there are many studies related to perceptual adaptation and time compressed speech, still there is a scarcity of Indian studies. Salian, Dhamani and Rajashekhar (2008) studied the perception of time compressed speech which had temporal envelope and fine structure cues in adults and children using cochlear implants. Not many studies are available in Indian languages on the perceptual adaptation to natural fast sentences. The present study is aimed at carrying out as an extension of the study of Adank and Janse (2009) to investigate perceptual adaptation to natural fast sentences before and after time compressed speech in the presence of noise in Kannada language.

The study aims at exploring the performance of young adults in perception and perceptual adaptation of sentence stimuli in natural fast and time compressed speech mode in the presence of background noise.

Method

Participants

Twenty four native speakers of Kannada (8 males and 16 females) with an age range of 20 to 30years (Mean age 23.6years) participated in the study. The participants had no speech, language or hearing impairment or neurological /psychological disease. The subjects reported to have no prior experience with the time compressed speech. Prior to the testing, Hearing evaluation of all subjects were done using GSI-61 Clinical audiometer and the thresholds were confirmed to be within normal limits.

Stimulus

The stimuli included 75 Kannada Quick Sin sentences (Avinash, Meti & Kumar, 2010) recorded by a twenty four year old male speaker who was exposure to native Kannada language for almost 20 years. The selected sentences were recorded in two different modes; Normal mode and Natural fast mode, in a sound treated room using a Frontech external microphone (SSD-HP-202) into a Sony Vaio (EB24) laptop computer. The PRAAT software, 5.1.22 version (Boersma & Weenink, 2008), was used to record the sound at sampling rate of 44100 Hz. In the Normal mode, the speaker was instructed to read the sentences in quiet using a Normal speech rate. Next, the natural fast sentences were recorded by instructing the speaker to read the sentences four times in quick succession. Out of these, the second (or third in few occasions) sentence was selected as the fastest but still most fluent of the four sentences produced. Zero crossing was performed for all the sentences to get the absolute onset and offset timing of sentence. On an average, sentences in Normal speed consisted of 4.81syllables per second. However, natural fast sentences were of 11.37 syllables per second. Thereby, natural fast sentences were produced at 42.56% of the duration of normal speed sentences.

As a next step, Pitch Synchronous Overlap and Add (PSOLA) in PRAAT, was used to obtain the Time compressed sentences. Each sentence was time compressed using a Compression ratio, obtained by comparing the Normal and Natural fast sentences. For instance, if the ratio between a selected normal and natural fast sentence is 40%, then the time compression will be done at 40% for that particular sentence. Also, the intensity levels of all sound files were scaled to 70 dB Sound Pressure Level. Lastly, four talker babble at 0 dB SNR was added to all the recorded sentences using a Matlab in order to produce a more naturalistic auditory condition.

Procedure

Each participant (tested individually) was seated comfortably in the room and given appropriate instructions. A total of 5 sentences were given as practice trials in the beginning. These trials were not included in the test. To measure the adaptation, a total of 75 sentences (25 in each mode, Normal, natural fast and time compressed) were presented in two experimental designs,

1) Normal speech - Natural fast - Time compressed mode and
2) Normal speech - Time compressed - Natural fast mode

Stimulus presentation and reaction time measurements were done using DMDX software (version 4.0.3.0), with Frontech external microphone (SSD-HP-203) into a Sony Vaio (EB24) laptop computer. Each participant's reaction time and word frequency accuracy was calculated.

The significance differences between three experimental conditions was assessed by a repeated measure ANOVA test using SPSS software (version 17)

Results

Accuracy

Twenty four subjects participated in the study. The study aimed at measuring the response accuracy and mean reaction time for subject's response. The accuracy of responses was measured as the number of words repeated correctly, per sentence.

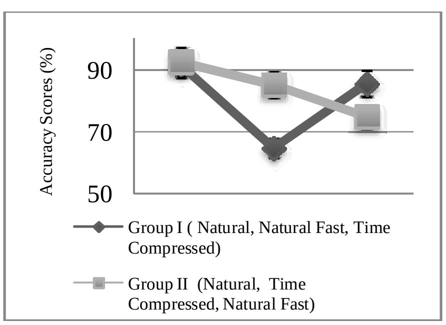

Figure 1*: Shows the mean accuracy scores of subjects for sentences in normal speed, artificially time compressed mode and normal speech rate across Group I and Group II*

The mean percentage correct scores for speech perception is showed in Figure 1 for Normal rate Speech (Mean scores- group 1- 85.45 & Group 2- 85.76), Time Compressed Speech (Mean score- Group1- 91.81 & Group 2- 92.57) and Natural fast Speech (Mean scores- Group 1-64.67 & Group 2- 74.78).

Thereby the overall scores indicated Normal speech mode as being better than other two modes in both the experimental conditions. Moreover, the accuracy scores of sentences in natural fast mode were poorer than time compressed mode when compared to the normal mode sentences. In addition, adaptation effect was observed as the test preceded the twenty-fifth sentence, especially in natural fast mode. It was observed that the responses improved in accuracy with increase in time. Although, in case of the time compressed speech, adaptation effect was less prominent as the exposure time increased.

The ANOVA results indicated a significant main effect of condition for both first [F (1.74, 19.14) = 295.21, $p<0.001$] and second experimental conditions [F (1.76, 19.36) = 65.58, $p<0.001$]. For each condition, the results were compared with the other two conditions using Pair wise comparisons with Boneferroni adjustments. The data showed statistical significance ($p <0.05$) by the post hoc test when the Normal speech mode was compared with Natural fast mode and Time compressed mode conditions, in both experimental designs.

Reaction Time Measurement

The mean reaction time scores is showed in Figure 2 for Normal rate Speech (Mean scores- group 1- 333.86 ms & Group 2- 351.50ms), Time Compressed Speech (Mean score- Group1- 714.07 & Group 2- 735.32) and Natural fast Speech (Mean scores- Group 1-953.17 & Group 2- 784.97).

Reaction time measurements were longer for both natural fast and time compressed speech when compared with normal sentences. In both natural fast and time compressed speech, listeners took more time to react correctly to the presented stimuli. Reaction time became further poor as the sentences were pooled with speech babble. In some, the reaction time analysis shows that listeners responded fastest to the normal-speed sentences, slower for the time-compressed sentences and slowest for the natural fast sentences. Overall the reaction time for group II was less for natural fast sentences. However the reaction times were not significantly different for the order of stimuli presentation. Whereas adaptation to time compressed speech did not show improved accuracy over trials, but showed decreased reaction times over trials. Regulation to natural fast speech was found both in improved accuracy and in considerable decreased reaction times over trials

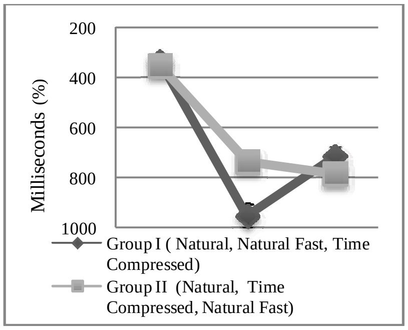

Figure 2: Average reaction times in millisecond for Normal sentences, Time compressed and Natural fast across Group 1 and Group 2.

Discussion

The study aimed at observing individual adaptation to natural fast sentences presented in degraded conditions and thus comparison of this adaptation to time compressed sentences. Two groups of participants were involved in the study and were presented with sentences in three specified modes but in different order for each experimental condition.

Results of the present study shows adaptation of listeners to natural fast speech. Natural fast speech involves greater variation in spectral as well as temporal aspects compared to artificially time compressed speech (Adank & Janse, 2009; Bent, Buchwald, & Pisoni, 2009). Thus, natural fast speech is always difficult in perception relative to both time compressed and normal speech sentences. This is possibly due to its spectral and temporal variations. Also natural fast speech possesses greater amount of co articulatory postures which makes it difficult to process in the natural listening environment. The scores of accuracy obtained for natural fast speech were considerably low when compared to other two modalities. Addition of speech babble at 0dB SNR made the task quite difficult and further responses measured also shows an increased reaction time. Performance of speech in artificially time compressed mode was better than the natural fast mode, as artificially time compressed speech has variations only in temporal aspects whereas its spectral contents were intact. But adaptation process in artificially time compressed speech was less seen than that of natural fast speech and the accuracy scores in artificially time compressed speech were almost similar to that of normal speech mode. The reason for this may be explained in terms of better spectral residue in the speech content. The better performance was also reflected in reaction time measurements where it was better and reduced than that of natural fast mode.

The present study also attempted to compare the perceptual adaptation of natural fast speech in relation with artificially time compressed speech. The second group (Normal- time compressed-natural fast) showed higher accuracy for the natural fast materials. The main reasons for such results is that listeners from this group already being adapted to temporally altered speech material (time compressed speech) than natural fast sentences which has alterations in both spectral as well as temporal aspects. This phenomenon confirms the view that auditory system adapts to the stimulus presented in a particular context over a period of time.

The listeners in the first group (normal- natural fast- time compressed) didn't show any considerable adaptation from natural fast speech to time compressed speech, as the accuracy rates were almost similar for time compressed speech materials in both groups. But both groups showed reduction in reaction time measurements over sentences. In the study, the time-compression ratio varied according to the natural fast sentences. It is unclear how this may have affected the adaptation in participants. Studies show that phonetic inconsistency in the experiment will assist in perceptual learning (Logan, Lively & Pisoni, 1991). Compression ratio can also lead to decline in the performance (Dupoux & Green, 1997), where as there are contradictory studies on positive relation between performance and compression ratio (Golomb et al., 2007).

Study confirms previous research done by Janse (2004) and Adank and Janse (2009). The scores obtained for natural fast speech in the present study were lower when compared to study done by Adank and Janse (2009), which can be attributed to the introduction of speech babble at 0dB SNR. According to Pavlovskaya & Hochstein (2004), if an easy task is followed by a complicated task, there will be a transfer of learning. However same thing won't happen when an complicated task is followed by an easier task. This view was supported from the study as the listeners in the second group who were exposed to time compressed speech before natural fast speech performed well and not the first group which was presented with natural fast speech prior to time compressed speech. Another factor which might contribute for the poor performance in natural fast sentence was coarticulatory effect and assimilation, which results in deletion of segments, decreased vowel durations and reduction of unstressed vowels.

Clinical Implications

According to literature, geriatric population and persons with stroke generally have more trouble with natural fast speech. Thus introducing the time compressed speech in the rehabilitation approach can facilitate perceptual abilities to process naturally produced fast speech. In the perception of natural fast sentences in the environment are multifaceted to children with Cochlear Implantation. Hence training these children with time compressed speech in the clinical setting as well as in home environment will improve their speech perception abilities. Further, effect of time compression speech on adaptation have to be evaluated in individual with hearing loss and other pathologies which impairs speech perception abilities. Future research can also focus on comparison of speech perception abilities across adults, geriatrics and pediatric group, especially in children with cochlear implant and adults with stroke.

Conclusions

The present study focused to measure the perceptual adaptation of natural fast sentences in young adults and correlated this adaptation with respect to time compressed speech sentences. The results showed perceptual adaptation effect of young adults on natural fast speech as well as on time compressed speech. Exposure to time compressed speech prior to natural fast speech significantly increased the word accuracy and reduced response reaction time. The study provides us an insight about how listeners process a naturalistic distortion in the speech signal and in turn helps in learning more about human's general speech comprehension ability. The results of the present study show the importance of adaptation effect to degraded signal in the normal hearing individuals.

References

Adank, P., & Janse, E. (2009). Perceptual learning of time-compressed and natural fast speech. *Journal of acoustic society of America, 126, 5,* 2649-2659. doi: org/10.1121/1.3216914

Alho, J. (2010). Role of the speech motor system in speech perception. Retrieved from http://lib.tkk.fi/Dipl/2010/urn100236.pdf.

Avinash, M. C., Meti.R.., & Kumar, U., (2010). Development of Sentences for Quick Speech-in-Noise (QuickSin) Test in Kannada. *Journal of Indian Speech and hearing Association, 24* (1), 59-65.

Bent, T. V., Buchwald, A., & Pisoni, B.D. (2009). Perceptual adaptation and intelligibility of multiple talkers for two types of degraded speech. *Acoustic society of America,126, 2660-2669.*

Boersma, P., & Weenink, D. (2008). Praat: Doing Phonetics by computer (Version5.0.17) [Computer Program]. Retrieved from http://www.praat.org/

Browman, P., & Goldstein, L. (1990). Gestural specification using dynamically defined articulatory structures. *Journal of phonetics, 18,* 299-320.

Byrd, D., & Tan. (1996). A Phase Window Framework for Articulatory Timing. *Phonology, 13,* 139-169. doi: 10.1017/S0952675700002086

Bradlow, A. R., & Bent, T. (2007). Perceptual adaptation to non-native speech. *Cognition 106,* 707-729, doi:10.1016/j.cognition.2007.04.005

Byrd, D., & Tan, C. C. (1996). Saying consonant clusters quickly. *Journal of Phonetics*, *24***,** 263 – 282.

Dupoux, E., & Green, K. (1997). Perceptual adjustment to highly compressed speech: effect of talker and rate changes. *Journal of Experimental Psychology: Human Perception and Performance. 23,* 914-923.

Ernestus, M. (2002). The recognition of reduced word forms. *Brain and Language, 81, 3,* 162-173, doi:10.1006/BRLN.2001.2514

Golomb, D. J., Peelle, J. E., & Wingfield, A. (2007). Effects of stimulus variability and adult aging on adaptation to time-compressed speech. *Acoustic Society of America, 121, 1701- 1708.* doi: org/10.1121/1.2436635.

Green, P., Cook, M., & Crawford, M. (1994), Handling missing data in speech recognition. *International Conference on Spoken Language Processing (ICSLP-94), Yokahama, Japan*

Holt, L. L. (2008). Speech Perception within an auditory cognitive Science framework. *Carnegie Mellon University Research Showcase, 1,* 1-7. doi: 10.1111/j.1467-8721.2008.00545.x

Janse, E. (2004). Word perception in fast speech: artificially time-compressed vs. naturally produced fast speech. *Speech Communication, 42, 2,* 155-173, doi:10.1016/J.SPECOM. 2003.07.001

Koreman, J. (2006). Perceived speech rate: The effects of articulation rate and speaking style in spontaneous speech. *Journal of Acoustic society of America 119, 1,* 582-596, doi: ORG/10.1121/1.2133436

Lehiste, I. (1970). Suprasegmentals. *The MIT press, 55 Hayward Street Cambridge, MA 02142 USA.*

Lisker, L. (1973). On explaining vowel duration variation. *Haskins laboratories, New haven, con, SR 37/38.*

Logan, J. S., Lively, S. E., & Pisoni, D. (1991). Training Japanese listeners to identify English /r/ and /l/: A first report *Journal of acoustic society of America. 89*, 874–886.

Max, L., & Caruso, A. J. (1997). Acoustic Measures of Temporal Intervals Across Speaking Rates; Variability of Syllable- and Phrase-Level Relative Timing. Journal of Speech, Language, and Hearing Research,.40, 1097-1100.

Miller, J. L., & Liberman A. M. (1979). Some effects of later-occurring Information on the perception of stop consonant and semivowel. *Attention, Perception & Psychophysics. 25,* 457-465. doi: 10.3758/BF03213823.

Miller, L. J., Grosjean, F., & Lomanto, C. (1984). Articulation Rate and Its Variability in Spontaneous Speech: A Reanalysis and Some Implications. *Phonetica, 41*, 215-225. doi: 10.1159/000261728.

Pallier, C., Dupoux, E., & Galles, N. S. (1998). Perceptual adjustment to time-compressed speech: a cross-linguistic study. *Memory and cognition 26,* 844-851, doi: 10.3758/BF03211403.

Pavlovskaya, M., & Hochstein, S. (2004). Transfer of perceptual learning effects to untrained stimulus dimensions. *Journal of Vision, 4, 416*. doi: 10.1167/4.8.416

Peelle, J., & Wingfield, A. (2005). Dissociations in Perceptual Learning Revealed by Adult Age Differences in Adaptation to Time-Compressed Speech. *Journal of Experimental Psychology: Human Perception and Performance, 31, 6*, 1315–1330, doi: 10.1037/0096-1523.31.6.1315.

Salian, S. K., Dhamani, I., & Rajashekhar, B. (2008). *Role of temporal envelope and fine structure cues on time compressed speech recognition in adults and children using cochlear implants.* Cochlear Implant Group of India Conference, India.

Sebastian-Galles, N., Dupoux E., Costa A., & Mehler J. (2000). Adaptation to time-compressed speech: Phonological determinants. *Perception and Psychophysics, 62*, 834-842

Wouters, J., & Macon, M. (2002). Effects of prosodic factors on spectral dynamics Analysis. *Journal of Acoustic Society of America, 111,* 417-427, doi: ORG/10.1121/1.1428262

TELEPRACTICE IN A PERSON WITH APHASIA

[1]Goswami S.P., [2]Ankita Bhutada, & [3]Kavitha Jayachandran

Abstract

"TELEPRACTICE" (Source, Professional Issues in Telepractice for SLP) is defined as "The application of telecommunications technology to deliver professional services at a distance by linking clinician to client, or clinician to clinician for assessment, intervention, and/or consultation" (ASHA, 2004). There is a discrepancy between the available manpower, and ratio of individuals with communication disorders. It has been well documented that the traditional service delivery system of Speech language pathology does not suffice to the needs of individuals with disability in the rural and in urban area. The present study aimed at assessing the efficacy of "telepractice" for rehabilitation of a person with Aphasia with respect to Indian context. This was a single case study on a person with Broca's Aphasia who was assessed using the Face to Face (FTF) assessment and intervened using Skype via web camera system. The intervention was focussed on Expression, Repetition, Naming and Memory based on Manual for Adults Aphasia Therapy in Kannada (MAAT-K). Each session was audio recorded and was subjected to linguistic analysis. The results were analyzed as the baseline scores, mid therapy and post therapy scores. The results revealed there was significant improvement in the domains of Expression, Repetition, Naming and Memory. Also the impact of communication, activity limitation and emotional wellbeing was assessed using the sub-scales of The Burden of Stroke Scale (BOSS) i.e., The Communication Difficulty (CD), The Communication Associated Psychological Distress (CAPD), the Negative Mood Scale and the Positive Mood Scale and results revealed significant improvement in the domains of (CD) and(CAPD). Thus, telepractice is effective in the Indian context and is an upcoming area in the field of speech language pathology. It is vital to accelerate programs of research and clinical endeavours in this area to improvise the service delivery system.

Key words*: Face to Face (FTF) assessment, Manual for Adults Aphasia Therapy in Kannada (MAAT-K), The Burden of Stroke Scale (BOSS).*

Speech language pathology deals with providing effective services for persons with communication disorders, which is on a constant rise in the recent past. Traditionally the service delivery system of a Speech Language Pathologist involves providing direct therapy i.e., Face to Face (FTF) interaction with the persons with communication disorders. The other mode of therapy is indirect, which targets the parent or the caregiver to provide therapy which is constantly being guided and monitored by a qualified Speech Language Pathologist.

According to the National Sample Survey Organization's (2002) 58th round report on disability, the population in India suffering from communication disorders (Speech Disorder) is about 2.15 million persons (11.6% of total disabled population). The prevalence rate of speech disability (per million) in rural area was about 220 and 193 in urban areas (Tiwari, Krishnan, 2011).

There is a vast discrepancy between the manpower available to meet the needs of individuals with communication disorders who are deprived of quality services and benefits from speech language pathologists. The accesses issues for persons living in rural and remote areas where there are inevitably fewer numbers of SLPs are clear (Pickering et al., 1998). This remains a vexing issue for public health and education systems worldwide. Of equal concern are persons residing in urban areas where access to services may also be difficult due to disability, mobility, and financial issues, restrictive work schedules, and family support needs Theodoros (2011). Hence, there is a pressing need to provide effective services to people with communication disorders who cannot avail appropriate and timely services from speech language pathologist.

There has been global advancement of technology worldwide across various fields of health science. Where traditional mode of therapy falls short, it would be remarkable to exploit the upcoming technology to bridge the gap between the recipients' and the service providers. According to Internet usage Statistics

[1]Professor in Speech Pathology, AIISH, Mysore-06, Email: goswami16@yahoo.com, [2]Student, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: anks.bhutada@gmail.com, & [3]Research Associate, AIISH, Mysore-06, Email: slp.kavithaj@gmail.com

and Telecommunication report, in 2010, 8.5% of population that covers 100,000,000 (www.internetworldstats.com) users have access to the internet, thus telecommunication can be a plausible mode to provide services. There have been various terinologies used interchangeably in the field of telecommunication for service delivery such as “telerehab”, “telemedicine”, “webnar” and so on. However, according to the position statement developed by ASHA in 2004-2005, ASHA has adopted the term “TELEPRACTICE” (Source: Professional Issues in Telepractice for SLP). They define it as “The application of telecommunications technology to deliver professional services at a distance by linking clinician to client, or clinician to clinician for assessment, intervention, and/or consultation (ASHA, 2004).

Various platforms have been developed to support service delivery in telepractice and this falls under two broad headings: synchronous (in real-time) and asynchronous (offline) service delivery. The types of technology used in telepractice research have included the Plain Old Telephone Service (POTS) (Carey et al., 2010; Wilson, Onslow, & Lincoln, 2004), videophones (Tindall, Huebner, Stemple, & Kleinert, 2008), conventional videoconferencing (Myers, 2005), Personal Digital Assistants (PDA) (Halpern, et al., 2005), computer-based programs (Thompson, Choy, Holland, & Cole, 2010) and customized multi-media videoconferencing systems (Constantinescu et al, 2010b; Georgeadis, Brennan, Barker, & Baron, 2004; Theodoros, Hill, Russell, Ward, and Wootton, 2008), web camera and video-conferencing via Skype (Howell, Tripoliti & Pring, 2009) .

A number of studies have successfully proved “Telepractice” as one of the service delivery methods for assessment and intervention for Adult Neurogenic Communication disorders. Hill & Theodoros (2002) reviewed the role of tele-rehabilitation in speech-language pathology and have provided evidences of its efficacy dating from 1976 where Vaughan (1976, 1977 & 1979) used “Tele-communicology” a method that used telephone adjuvant with teaching machine to provide visual aids, auditory practice material etc. There has been abundance of literature generated in the western population from then on to the present day.

The line of research in telepractice generally deals with comparison of assessment/ therapy between two settings (i.e.,) Face to Face (FTF) therapy versus telepractice. Brennan, Georgeadis, Baron, and Barker (2004) compared computer-based videoconferencing to traditional (FTF) sessions in the assessment of adults with acquired brain injury on a story-retelling task. The results revealed that there were no significant differences between the two settings for the entire group. Similarly, Palsbo (2007) compared stand-alone video-conferencing equipment with face-to-face assessment in the assessment of functional communication and the results revealed a high percentage level of agreement within the 95% limits of agreement, with a range of 92% to 100%, indicating that assessment conducted in the two settings for this assessment protocol were equivalent.

An extensive research was done on 32 participants with mild to severe aphasia (Theodoros, Hill, Russell, Ward, & Wootton, 2008; Hill, Theodoros, Russell, Ward, & Wootton 2009), and 11 participants with mild to severe apraxia of speech (Hill, Theodoros, Russell, & Ward, 2009b). They were assessed in a laboratory setting using a custom-made PC-based multi-media video-conferencing system. These assessments were conducted simultaneously online and face-to-face (FTF). The findings from these studies included good strength of agreement between the online and FTF assessors for oro-motor performance and perceptual ratings of speech for the dysarthics speakers, with high inter- and intra-rater reliability across all parameters. Hill, Theodoros, Russell and Ward (2009a). No significant differences between test scores on the Apraxia Battery for Adults-2 (Dabul, 2000) were found for the online and FTF assessments. In addition, moderate to very good agreement was obtained for the online and FTF ratings of apraxia of speech (Hill, Theodoros, Russell & Ward, 2009b).

Similarly, no significant differences were determined between the online and FTF test scores on the Boston Aphasia Examination 3rd Edition (Goodglass, Kaplan & Barresi, 2001) with moderate to good agreement for assessor ratings, and good to very good intra- and inter-rater reliability for the majority of the online ratings (Theodoros et al., 2008). This study also stated few issues encountered during online assessment for persons with aphasia which made evaluation of naming and paraphasia, as well as apraxia of speech challenging. Thus, all the above stated literature provide sufficient evidence that telepractice may be an effective alternative to the traditional means of assessment and holds promising mode to outreach people on mass.

The studies have also evaluated efficacy of online and offline therapy using telepractice.

Cherney, Holland, and Cole, (2008) documented the use of Aphasia Scripts, a software program (offline) which uses a virtual therapist to provide conversational script training on persons with aphasia. The results showed that the verbal output of three participants improved in content, grammatical productivity, and rate following therapy. A web camera and video-conferencing via Skype was used by Howell, Tripoliti, & Pring (2009) to deliver Lee Silverman Voice Therapy to three people with Parkinson's disease (PD) in combination with FTF treatment. The participants received one treatment session per week FTF and the remaining three sessions via Skype. As accurate recordings of Sound pressure level (SPL) via Skype could not be obtained, the weekly FTF session was used to record vocal SPL using a sound level meter. This study found that remote treatment resulted in gains in SPL for sustained phonation, reading, and conversational speech consistent with previous FTF treatment.

Similarly, a single case study by Constantinescu, Theodoros, Russell, Ward, Wilson, and Wootton (2010a) used a public telecommunication system on a person with PD. The results revealed substantial improvements in SPL in sustained phonation, reading and conversation and in overall speech intelligibility following the treatment. Hence, the studies mentioned above provide an insight of the feasibility of using telepractice as a possible alternate mode for service delivery.

Where there is plethora of literature regarding telepractice in western population there is dearth of the same in India. Hence, there is a dire need to adopt this model of service delivery to the Indian Context and establish its efficacy across disorders. This may enable to enhance the quantity and quality of services for people in the rural and urban areas.

Need for the study

The scope of telepractice in the Indian context is an avenue which remains to be explored. With advancement in technology it is vital to determine how this development can aid to serve the people with communication disorders. Hence, there is a pressing need to conduct research along this line.

Aim of the study

This study attempted at assessing the efficacy of telepractice for rehabilitation of a person with Aphasia. This study may serve as a stepping stone to generate Evidence Based Practice (EBP) in the field of telepractice for persons with aphasia.

Method

A 62 year old right handed male served as the participant for the study. He was a native speaker of Hindi (L1) and was equally proficient in English (L2). He suffered from an episode of stroke on 5th of April 2011. Results of the CT scan revealed the presence of severe diffuse stenosis of left Internal Carotid Artery (ICA). He exhibited symptoms of motor and language impairment post onset of stroke. Eventually, there was restoration of the motor functions, but not the verbal language. He showed obvious difficulty in recall of words, repetition, naming and expression. Subsequently a FTF assessment was conducted by a speech language pathologist and he was diagnosed as having Broca's Aphasia based on the Western Aphasic Battery (WAB) given by Kertez and Poole (1982). He was recommended for telepractice using Skype (Version 5.5) via web camera as direct therapy was not possible due to some practical reasons. He attended 25 speech language therapy sessions through Skype from All India Institute of Speech and Hearing, Mysore from 10th of August 2011 onwards. He was provided five sessions per week with each session lasting approximately 45 minutes.

Tasks and stimuli material

It has been well documented and observed by professionals that the traditional therapy does not fit into a person's need based protocol. During the online treatment on day to day basis, a profile was developed and evaluated for the participant's various activities which were taken from his need based protocol. A total of 25 sessions were considered for this study. The participant was provided speech and language therapy in both L1 and L2 by adapting the Manual for Adult Aphasia Therapy in Kannada (MAAT-K) to Hindi (L1) and English (L2).

MAAT-K was the cumulative outcome of Manual for Adult Non-Fluent Aphasia Therapy- in Kannada (MANAT-K) and Manual for Adult Fluent Aphasia Therapy- in Kannada (MAFAT-K) which was field tested by Goswami, Shanbal, Samasthitha and Navitha (2010) and Goswami, Shanbal, Chaitra and Ranjini (2011) respectively. This manual consisted of six domains: Functional Communication (FC), Repetition (R), Comprehension and Expression (C & E), Naming (N), Reading and Writing (R &W) and an additional section on treatment for Apraxia of speech and oro-motor exercises. The domains targeted for the participant were Repetition, Expression and Naming based on linguistic profiling. The sub sections of repetition, expression and naming were used. The repetition task consisted of environmental stimuli; expression task consisted of activities related to daily routines, free recall narrations, descriptive and procedural. These activities were basically the basis for discourse. Confrontation naming, Lexical generative naming (Phoneme fluency, word fluency, category specific) and Responsive naming were the tasks included under naming section.

In addition to the above mentioned tasks for naming, few other sections were added to improve the participant's fluency at a broader level. The tasks included were cluster fluency, category specific fluency (perceptual, semantic and lexical), semantic mapping, and sentence fluency. In addition, symptomatic therapy was also provided for memory using a resource manual for mild traumatic brain injury by Green, Stevens and Wolfe (1997).

The therapy techniques used were cueing hierarchy wherein phonemic, semantic and rhyming cues were provided online via the microphone attached with the laptop. Wherever need for orthographic cues arose, the target phoneme was typed using the short message service (SMS) option available on Skype which served to provide online orthographic cue. De-blocking and Language Oriented Therapy (LOT) were also used as language therapy techniques. All the sessions were audio recorded and were subjected to linguistic analysis to monitor the error pattern and improvement in performance. To measure the participant's communication difficulty, subscales of the Burden of Stroke Scale (BOSS) were used. BOSS is a comprehensive patient reported measure of functioning (activity limitation) and well being (Doyle, Mcneil, Hula, & Mikolic, (2004). The Communication Difficulty (CD) section that consisted of seven items, the Communication Associated Psychological Distress (CAPD) section that consists of three items, the Negative Mood Scale and the Positive Mood Scale were used to measure the patient related outcomes. Both pre and post therapy ratings were obtained from the participant for all the subscales.

Procedure

The participant was provided profile based telepractice therapy using Skype via web camera. All the therapy sessions were conducted in a quiet room, free from any distraction. A pre-requisite protocol was developed to ensure effective communication during the therapy sessions. The protocol is shown in Table-1.

Scoring and analysis

The audio sample of every session was analyzed and the results were documented on a treatment recording sheet (adapted from MAFAT-K, Chaitra & Goswami, 2010). The analysis of sample was done based on the scoring provided in MAAT-K, 0 symbolized no response/incorrect response/unintelligible response, ½ for partially correct and intelligible response and 1 for fully correct and intelligible response. An average was obtained for every domain (except discourse) using the formula mentioned below.

$$\text{Average Scores} = \left(\frac{\text{Scores obtained by the participant}}{\text{Number of trials used}} \right) \times 100$$

The analysis for discourse was done by calculating the number of paraphasic / circumlocution/perseveratory errors and it was expressed as a percentage of the total number of words spoken.

$$\text{\% of errors} = \left(\frac{\text{No. of paraphasic errors}}{\text{Total No. of words spoken}} \right) \times 100$$

The analyses for the samples were done across three conditions, i.e., the initial session (1 and 2), middle session (12 and 13) and final session (24 and 25).

The BOSS scale was mailed across to the participant at the end of 25^{th} session to obtain a feedback on participant related communication difficulty. The scores of BOSS scale were linearly transformed using the metrics of (0-100), using the following formulae.

$$\text{Transformed Score of BOSS} = \left(\frac{\text{Actual raw Score} - \text{Lowest possible Score}}{\text{Possible raw score range}} \right) \times 100$$

A score of 100 represented least desirable health state that means greater activity limitation and greater emotional distress, whereas score of 0 represents most desirable health state and score between the ranges represents percentage of total score.

Table 1: *Pre requisite protocol*

Requirements		Pre requisite
		2 Microphones, video, desktop sharing, facility to record the sessions and facility to maintain the privacy of session recordings.
Initial face to face interview		Preferable
Knowledge of computer operation		Yes
Manual dexterity		Required
Sensory issues		Nil
Connection bandwidth		128- 384 kbps
Transmission lag		Minimal (0.5 sec)
Place of contact		Home
Point of contact		Telephone number (preferably mobile)
Sessions given		25
Assessment	No. sessions	1
	Tests used	WAB
Treatment	Sessions/ week	5
	Duration of session	45 min (+10 minutes to check the connectivity)
	Materials required	Comfortable seating of the client and clinician, video camera, desktop sharing program to share the reading material, scoring and to give online feedback.
Process study	Stakeholder satisfaction	Questionnaire (BOSS)

Results and Discussion

The present study was assessed the efficacy of telepractice on a person with aphasia. The participant was provided therapy based on MAAT-K and the results were tabulated (Table 2) across three conditions. The Scores of BOSS have also been tabulated in Table 3.

Table 2: *Performance of the participant across three conditions*

Domains	First session	Twelfth session	Twenty fifth session
REPETITION			
• Vocabulary	68.5%	85%	87.5%
EXPRESSION (% of errors)			
• Daily routines	11.66%	5.64%	0%
• Free recall narration	11.00%	6.36%	1.7%
• Descriptive	15.00%	7.7%	2%
• Procedural	17%	7%	1%
LEXICAL GENERATIVE NAMING			
• Phoneme fluency			
1. L1	72.08%	87.5%	91%
2. 2	70.03%	82%	90%
3. Alternating fluency	L1- 75%, L2-59.3%	L1-81%, L2-78%	L1-87%, L2-84%
• Cluster fluency			
1. L1	65%	70.7%	5%
2. L2	73.3%	78.5%	91%
• Category specific			
1. Perceptual semantic	75%	81%	86%
2. Lexical	90%	100%	100%
• Semantic mapping	50%	100%	100%
• Sentence fluency (% of error)	31%	26.78%	14.93%
1. L1			
2. L2	10%	7.69%	6%
MEMORY			
• Auditory sequencing			
1. Forward	60%	58.3%	44.4%
2. Backward	83.3%	55.5%	100%

The results revealed that there was a trend of consistent improvement across sessions in all the domains. There was differential performance between languages i.e., L1 and L2 across sessions. Improvement in performance was evident by the decrease in error percentage (sentence fluency, expression) and increase in overall percentage of success (repetition, lexical generative naming and memory). It can be stated from Table 2, that the repetition skills of the participant improved from first session to twenty fifth session. The percentage of correct repetition skills was 68.5% while in twelfth session it was 85% and in twenty fifth session it was 87.5%. It is clear from these percentage score that the participant through telepractice showed an obvious improvement in his repetition skills. Thus, it can be stated that these linguistic skills can be facilitated using telepractice. The repetition skills which require cueing using multimodalities can be provided through this mode. However, the clinician needs to be clear, precise with appropriate rate of speech and pauses while presenting the stimuli. This mode of service delivery provides a better, easy and clear virtual graphics which were quite helpful in this person. This shows that for those persons with literate skills and a computer saviour, this is an apt mode.

His performance in the various domains of expression did show a clear trend of reduction in errors from first session to twenty fifth session. As illustrated in Table 2, his error percentage in first session was 11.66%,11%, 15% and 17% while for twelfth session was 5.64%, 6.36%, 7.7% and 7% and the twenty fifth session was 0%, 1.7%, 2% and 1% respectively for daily routine, free recall, descriptive and procedural tasks under expression. It is evident from these percentage values that under all the domains of expression the participant showed considerable improvement in his expressive skills. From the performance in these skills it can be explicitly stated that he showed an obvious improvement in the discourse level. During the session it was observed that cohesiveness was well maintained during spontaneous conversation as well as on structured tasks under expression skills. He showed a clear cut trend of using the PACE technique with ease .Thus from these results it is evident that a professional can use any available language technique to improve the expressive skills in persons with Aphasia.

These performances further strengthen the concept that telepractice does bring a difference in the overall expressive skills of persons with Aphasia who are literate and have an inclination towards the technology.

Performance of the participant under various subsections in naming task did improve from the first session to the twenty fifth session. His performance on the first session on L1 (Hindi) was 72.08% and 70.03% for L2 (English). He showed a clear improvement in L1 and L2 in twelfth session where he scored 87.5% and 82%. In the 25th session his percentage scores were 91% and 90% respectively for L1 and L2 for phoneme fluency task. Under Alternating fluency and cluster fluency tasks the scores for L1 and L2 showed a gradual trend of improvement wherein session one (L1 =75%, L1= 65%) and (L2= 59.3%, L2= 78%). By twelfth session scores were (L1 = 81%, L1=70.7%) and (L2= 78%, L2= 78.5%), whereas in twenty fifth session the scores were (L1 = 87%, L1=85%) and (L2= 84%, L2= 91%).

With respect to category specific naming (perceptual and lexical) the results showed a gradual significant improvement from the first session to the twelfth session and the scores were maintained by the twenty fifth session, the scores were as follows (75%, 90%), (81%, 100%) and (86%, 100%). Thus, the results unequivocally support that the naming has improved considerably. I t can be clearly stated that Telepractice permits the clinician to use all the cueing hierarchies used in face to face therapy. This in turn facilitated the naming skills. Furthermore with the help of telepractice it becomes convenient to provide graphic, auditory or visual cues separately or in combinations.

The performance scores for sentence fluency showed a trend of significant decrease in the error percentage across sessions which was as follows, first session (L1= 31%, L2=10%), twelfth session (L1= 26.78%, L2=7.69%) and twenty fifth session (L1= 14.93%, L2=6%). Thus, the trend shows that there was significant improvement in naming under various subsection and tasks. This corroborates that there was generalization of skills and hence a significant decrease in communication difficulty on the BOSS subscales.

The participant's performance score on memory which included Auditory sequencing showed the following trend for Forward sequencing across the three sessions, 60%, 58.3% and 44.4%, whereas for Backward sequencing the scores were 83.3%, 55.5% and 100%. Hence it was seen that there was considerable improvement across the memory skills. Thus, it paves way that even the cognitive skills can be improved using telepractice in persons with Aphasia.

Table 3: *BOSS scores*

Tests/variables	Pre-Therapy (%)	Post-Therapy (%)
Communication Difficulty (CD)	64.2%	14%
Communication Associated Psychological Distress (CAPD)	66.6%	33.3%
Negative Mood Scale	0%	0%
Positive Mood Scale	75%	75%

BOSS scores (Table 3) reveal that there was decrease in activity limitation and emotional distress which correlated with improvement in performance in speech and language therapy across sessions. Hence, it is inferred that there is a correlation between degrees of linguistic impairment to the participant reported communication difficulty.

Hence, the results indicate that telepractice is effective which is evident from improvement in performance as rated by the person and evaluated by the clinician. It is reiterated that speech language therapy must be customized based on need based profile of a person with Aphasia. This will maximize the generalization and hence reduce the activity limitation and emotional distress faced by the person with aphasia.

Thus the results of the study are quite encouraging which views telepractice as a promising approach to strengthen the service delivery for persons with aphasia. This has got more advantages over the face to face approach in terms of the mobility of the person, cost, accessibility, noise reduction as the stimuli is presented through the headphones as a result extraneous variables can be minimized. Moreover, the total cost involved in terms of travel, time and manpower can be used more effectively and accessibly which in turn facilitates the activity and participation of person in the society at large. Further, using telepractice neither the clinician nor the stake holder has to make any adjustment in the clinical setup especially with reference to disable friendly environment. This has received support from western literature where researchers have advocated the use of telepractice. Theodoros, (2011) has stated the efficacy of telepractice across age groups. This mode of therapy is more effective for the elderly who encounter issues like associated disability and mobility issues which make it challenging to maintain appointments.

Georgeadis et.al., (2004) stated that the other benefits of providing telepractice are that the patients do not need to travel and thus receives better access timely assistance at their own home. This mode of therapy is also cost-effective as the clinician does not have to travel, and the clinician can see multiple patients from one setting. Use of computer for providing speech-language therapy is interesting and increases the motivation of the stakeholder thus serves as a reinforcer.

Caution needs to be excised while prescribing telepractice as a mode of therapy for persons with aphasia. Detailed assessment must be carried out to evaluate the presence of pre requisite skills required to benefit from telepractice. An initial FTF assessment followed by telepractice will be a suitable model of service delivery for persons with aphasia. Also, persons with aphasia in the acute stage and those who require assistance with reading and writing skills may not be appropriate candidates for telepractice. Telepractice will also be beneficial option for persons who are recommended for regular follow ups.

There are few technical barriers which adversely affect the quality of telepractice. Connectivity availability and speed are critical issues as they interfere in online interaction by inducing a breakdown between the audio and video signal. Moreover in telepractice professional has to keep up the timing and should prepare well in advance for the session. Thus, a structural and professional approach using telepractice does bring a difference in the overall quality of life of a person with Aphasia. This telepractice works as a complement as well as supplement to FTF.

Conclusions

This study addressed the feasibility of using telepractice as a mode of therapy in the Indian context. Telepractice was provided to a person with aphasia using Skype via web camera for a total of 25 sessions. During the online treatment on day to day basis, a profile was developed and evaluated for the participant’s various activities which were taken from his need based protocol. Speech and language therapy was provided in both L1 and L2 based on MAAT-K. All the sessions were audio recorded and detailed analysis was done based on the scoring system of MAAT-K. The results revealed that there was consistent improvement in the domains targeted for therapy. The client feedback obtained using the BOSS scale also correlated with the improvement in language performance. Thus, this study provides evidence that telepractice is a feasible and an effective mode of therapy for persons with aphasia. Efficacy of this mode of therapy across age groups and disorders are avenues yet to be explored in the Indian context.

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Reference

American Speech-Language-Hearing Association, (2005). Speech-Language Pathologists Providing Clinical Services via Telepractice: Position Statement [Position Statement]. Available from www.asha.org/policy.

Brennan, D. M., Georgeadis, A. C., Baron, C. R., & Barker, L. M. (2004). The effect of videoconference-based telerehabilitation on story retelling performance by brain-injured subjects and its implications for remote speech-language therapy. *Telemedicine Journal and e-Health, 10,* 147-154.

Carey, B., O'Brian, S., Onslow, M., Block, S., Jones, M., & Packman, A. (2010). Randomized controlled non-inferiority trial of telehealth treatment for chronic stuttering: the Camperdown program. *International Journal of Language and Communication Disorders, 45*, 108-120.

Chaitra, S. & Goswami, S.P. (2010). *Manual for Adult Fluent Aphasia Therapy in Kannada (MAFAT-K). (Articles based on Dissertation done at AIISH), Part-B Speech Language Pathology, Vol VII:* 2008-2009, 62-66, All India Institute of Speech and Hearing, Mysore, India.

Cherney, L. R., Holland, A.L., & Cole, R. (2008). Computerized script training for aphasia: Preliminary results. *American Journal of Speech-Language Pathology, 17*, 19-34.

Constantinescu, G., Theodoros, D.G., Russell, T., Ward, E.C., Wilson, S.J., & Wootton, R. (2010a). Home-based speech treatment for Parkinson's Disease delivered remotely: A case report. *Journal of Telemedicine and Telecare, 16*, 100-104.

Doyle, P., Mcneil, M., Hula, W., & Mikolic, J. (2003). The Burden of Stroke Scale (BOSS): Validating patient-reported communication difficulty and associated psychological distress in Stroke survivors, *Aphasiology*, *17*:3, 291-304.

Doyle , P.M., McNeil, M.R., Mikolic, J.M., Prieto, L., Hula, W.D., Lustig, A.P., et al.(2004). The burden of Stroke scale (BOSS) provides valid and reliable score estimates of functioning and well-being in stroke survivors with and without communication disorders. *Journal of Clinical Epidemiology, 57*, 997-1007.

Goodglass, H., Kaplan, E., & Barresi, B. (2001). *Boston Diagnostic Aphasia Examination*

(3rd Ed.). Philadelphia: Lippincott, Williams & Wilkins.

Goswami, S.P., Shanbal, J.C., Samasthitha, S., & Navitha, U. (2010). Field testing of *Manual for Adult Fluent Aphasia Therapy in Kannada (MAFAT-K).* AIISH Research funded (ARF) Project Report.

Goswami, S.P., Shanbal, J.C., Chaitra, S., & Ranjini, M. (2011). Field testing of *Manual for Adult Non-fluent Aphasia Therapy-in Kannada (MANAT-Kannada).* AIISH Research funded (ARF) Project Report.

Goodglass, H., Kaplan, E., & Barresi, B. (2001). *Boston Diagnostic Aphasia Examination*

(3rd Ed.). Philadelphia: Lippincott, Williams & Wilkins.

Georgeadis, A., Brennan, D., Barker, L. M., & Baron, C. (2004). Telerehabilitation and its effect on story retelling by adults with neurogenic communication disorders. *Aphasiology, 18,* 639-652.

Halpern, A., Matos, C., Ramig, L., Petska, J., & Spielman, J. (2005). LSVTC- A PDA supported speech treatment for Parkinson's disease. Paper presented at *9th International Congress of Parkinson's Disease and Movement Disorders*. New Orleans, LA, USA.

Hill, A., & Theodoros, D. (2002). Research into telehealth applications in speech-language pathology. Journal of Telemedicine and Telecare, *8,* 187–196.

Hill, A.J., Theodoros, D.G., Russell, T.G., Cahill, L.M., Ward, E.C., & Clark, K (2006). An Internet-based telerehabilitation system for the assessment of motor speech disorders: A pilot study. *American Journal of Speech Language Pathology, 15* 1-12.

Hill, A.J., Theodoros, D.G., Russell, T. & Ward, E.C. (2009a). The re-design and re-evaluation of an Internet-based telerehabilitation system for the assessment of dysarthria in adults. *Telemedicine and eHealth, 15,* 840-850.

Hill, A., Theodoros, D.G., Russell, T., & Ward, E.C (2009b). Using telerehabilitation to assess apraxia of speech in adults. I*nternational Journal of Language and Communication Disorders 44,* 731-747.

Howell, S., Tripoliti, E., & Pring, T. (2009). Delivering the Lee Silverman Voice Treatment (LSVT) by web camera: a feasibility study. *International Journal of Language and Communication Disorders*, *44*, 287-300.

Internet Usage Stats and Telecommunications A Market Report-2010. Available from : URL: http://wwwi.nternetworldstats.com.

Kertesz, A. & Poole. (1982). *Western Aphasia Battery*. New York: Grune & Strraton.

Green, B.S., Stevens, K.M., & Wolfe, T.D.W. (1997). Mild Traumatic Brain Injury, A therapy and Resource Manual (1st Edn) San Diego: Singular Publishing Group, Inc.

Myers, C. (2005). Telehealth applications in Head and Neck Oncology. *Journal of Speech-Language Pathology and Audiology, 29,* 125-129.

Palsbo, S. E. (2007). Equivalence of functional communication assessment in speech pathology using videoconferencing. *Journal of Telemedicine and Telecare, 13*(1), 40-43.

Pickering, M., McAllister, L., Hagler, P., Whitehall, T.L., Penn, C., Robertson, S.J., et.al (1998). External factors influencing the profession in six societies. *American Journal of Speech-Language Pathology, 7,* 5-17.

Thompson, C.K., Choy, J.W.J., Holland, A., & Cole, R. (2010). Semantics: Computer-automated treatment of underlying forms. *Aphasiology, 24,* 1242-1266.

Tindall, L.R., Huebner, R.A., Stemple, J.C., & Kleinert, H.L. (2008). Videophone-delivered voice therapy: a comparative analysis of outcomes to traditional delivery for adults with Parkinson’s disease. *Telemedicine and eHealth, 14,* 1070-1077.

Tiwari, S. & Krishnan, G. (2011). Aphasia Rehabilitation in India: A preliminary survey of speech language pathologists. *Journal of All India Institute of Speech and Hearing, 30,* 108-116.

Theodoros, D.G., Hill, A.J., Russell, T., Ward, E.C. & Wootton, R. (2008). Assessing acquired language disorders in adults via the Internet. *Telemedicine and e-Health, 14,* 552-559.

Theodoros, D.G. (2011). Telepractice in Speech-Language Pathology: The evidence, the challenges, and the future. *Perspectives of Telepractice, 1,* 10-21.

Wilson, L., Onslow, M., & Lincoln, M. (2004). Telehealth adaptation of the Lidcombe program of early stuttering intervention: five case studies. *American Journal of Speech-Language Pathology, 13,* 81-93.

Wertz, R. T., Dronkers, N. F., Ellis, E. B., Shubitowski, Y., Elman, R., Shenaut, G., et.al (1987). *Appraisal and Diagnosis of Neurogenic Communication Disorders in Remote Settings.* In Clinical Aphasiology Conference, Lake of the Ozarks, MO

THE RELATIONSHIP OF AUDITORY AND VISUAL PERCEPTION WITH READING RELATED SKILLS

[1]Brajesh Priyadarshi, [2]Goswami S. P. & [3]Madhuban Sen

Abstract

Perceptual skills are regarded as important factors in the development of early reading skills. The current study seeks to identify the relationship of visual auditory perceptual variables with reading and its related skills in children of grade I to VIII. A total of 160 typically developing children (TDC) from standard I to VIII were taken, covering 20 children (10 males and 10 females) from each grade. Participants were divided into two groups according to the medium of instruction in the respective schools: TDC were being educated in a Hindi medium school (TDCH) and TDC who were being educated in an English medium school (TDCE). A Hindi adaptation of Early Reading Skills (ERS,) originally developed by Rae & Potter (1973), was administered in single 30 minute sessions. The descriptive analyses revealed homogeneity in the pattern of acquisition of perceptual skills. But the English medium children were found to have better scores on all the sections of perceptual skills. In all the grades, in both the groups, a statistically significant relation existed between all the perceptual parameters and reading related skills. None of the correlations were found to be statistically significant, except that between auditory perceptual composite score and structural analysis test score. The results of this study suggest that a perceptual deficit may hinder reading development in the elementary grades, but in higher grades a more complex interrelation of perceptual and reading related skills exist. Keeping in mind the results of this study may help avoid inaccurate assessment results or clinical reasoning, due to undetected or unsuspected perceptual deficits.

Key words*:* *Skills, development, acquisition.*

The passive process termed as sensation brings information from the outside world into the body and to the brain. The active process of selection, organization, and interpretation of the information brought to the brain by the senses, can be defined as perception. The components of perception include discrimination (judgments to define subtle differences), processing (ability to sequence meaningful language), memory (immediate recall), and/or comprehension (interpretation) (Gardner, 1985).

Visual perception is the process of recognition and interpretation of information taken in through the sense of sight and auditory perception is the process of recognition and interpretation of information taken in through the sense of sound. The mental organization and interpretation of the sensory information obtained through the visual modality is visual perception. The intent of visual perception is to attain awareness and understand the local environment, e.g., objects and events. Visual perceptual skills are important for learning how to form letters, copying, sizing, spacing, and orienting letters and words correctly. The development of visual perception occurs as a systematic increase in the ability to perceptually analyze and discriminate objects. The ability to identify, organize and interpret sensory information received through hearing is called auditory perception. Auditory perceptual skills impact the ability of children to benefit from instruction, follow directions, and participate in class discussions.

Visual auditory perceptual skills are regarded as important factors in the development of early reading skills (Smith & Dechant, 1961). Studies have reported significant correlations between perceptual skills and reading in the early primary grades (Bruininks, 1968). Studies on children of middle socio-economic status revealed moderate to high correlations between perceptual abilities and reading performance (Sterritt & Rudnick, 1966). Gardner (1985) and Badian (2005) found a relationship between perception and literacy readiness skills.

Visual memory was found to be integral to the reading process as established by Samuels and Anderson (1973). According to Whisler (1974), visual discrimination is an essential skill for reading readiness. Rosner (1975) suggests that visual perceptual skills are closely related to reading comprehension. Kavale (1982) performed a meta-analysis whose results indicated that visual perceptual skills are predictive of reading

[1]Lecturer in Linguistics, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: brajeshaiish@gmail.com, [2]Professor in Speech Pathology, AIISH, Mysore-06, Email: goswami16@yahoo.com & [3]Research Assistant, AIISH, Mysore-06

performance in school, especially during the preschool and primary school grades. A correlational study also lends support to this speculation (Slaughter, 1983). The visual sense has a pivotal role in the total process of intellectual development (Getman, 1984). Visual processing is significantly related to reading (Olson & Datta, 2002). These two researches also successfully established the relationship between visual discrimination and literacy readiness. Pammer and Kevan (2007) assessed visual discrimination skills and the results indicated that when controlling for Intelligence Quotient (IQ), visual discrimination accounted for the 6% variance reported in reading ability of the participants.

A strong relationship has been shown between auditory perceptual skills and primary grade reading achievement (Rosner, 1972). Correlational studies conducted by Burrows and Neyland (1978), concluded that auditory perception in kindergarten is indicative of reading success in later grades. Marston and Larkin (1979) found that the relationship between verbal and nonverbal auditory discrimination tasks and literacy success was significant. Kavale (1981) showed that a relation between perceptual skills and reading ability exists in preschoolers to grade VI. Watson and Miller (1993) found that a deficit in auditory perception holds lifelong consequences for literacy success.

Studies suggest that correlations between perceptual ability and reading appear to decrease with age. Bruininks (1969) found that the relation between perceptual abilities and reading performance in disadvantaged boys was low to moderate in magnitude. It was thus concluded that perceptual ability appeared to be more related to early reading skills than to their subsequent elaboration. Fazio (1997) also found no relationship between visual perception and literacy readiness. Research conducted later provided additional confirmation that poor and normal readers have comparable visual perceptual abilities (Fletcher, Shaywitz, Shankweiler, Katz, Liberman, Stuebing, & Shaywitz, 1999). Recent research has found a reciprocal relationship between auditory perceptual skills and literacy readiness (Cestnick & Jerger, 2000; Cestnick, 2001; Bretherton & Holmes, 2003).

The establishment of the relationships between visual and auditory perception and reading related skills may provide information to assist in the identification of linguistic deficits at the school level. Identifying deficits at the earliest age may advance the effectiveness of intervention. With the advancement of intervention, it is possible that literacy delays may be identified and remediated before children reach an age in which the delay becomes stigmatizing and debilitating to future scholastic success.

Need for the Study

The view that deficits in perceptual abilities may have a negative effect on reading related skills is still debatable. Especially in the Indian scenario, wherein the schooling system are organized differently in terms of government and/or private enterprises and as well as because there are different languages used as medium of instruction in different schools, there is an urgent need to investigate the relationship between perceptual abilities and skills related to reading. Previous studies have not included tests of perceptual abilities and their correlation with reading related skills in the same sample. Few studies have examined the relationship of perceptual abilities with reading performance in disadvantaged (lower SES) children. Children from a lower SES display marked perceptual deficiencies (Covington, 1962; Deutsch, 1964; Clark & Richards, 1966; McConnell & Robertson, 1967). Therefore, a study which attempts to address the above mentioned areas and tries to find out certain observations and facts related to these problems is much needed.

Aims of the Study

The present study seeks to identify the relationship of visual auditory perceptual abilities with reading and related skills in children of grades I to VIII. An understanding of this relationship in view of the Indian educational system may enhance the effectiveness of assessment and treatment of children with delayed literacy skills.

Method

Reading related skills' include five basic cognitive processes involved in reading: phonological processing, syntactic awareness, working memory, semantic processing, and orthographic processing (Siegel, 1993). It is not clear whether the above mentioned measures are appropriate for children from linguistically diverse backgrounds. This study uses a correlational research design to analyze the relationship among a large number of reading related variables, especially perceptual variables and predict the degree and direction of the relationships.

The test, a Hindi adaptation of Early Reading Skills originally developed by Rae & Potter (1973), included the following sections further divided into subtests: 1) Testing of perceptual skills included auditory identification**,** auditory recall, auditory discrimination and visual discrimination test (assessed in two separate levels). 2) Phoneme Grapheme Correspondence Test was assessed in two separate levels which required the child to identify the beginning consonant, ending consonant and vowel sounds in the spoken stimuli and the identification of consonants constituting a blend. 3) Structural Analysis section required the child to identify correct form of verb (in two levels) and to underline the root word in words with prefixes and/or suffixes (in the third level). 4) Blending was also assessed in two separate levels. 5) Oral Reading included four short passages arranged in the order of decreasing level of cohesion. The passages contained the following number of words: Passage 1 (44 words), Passage 2 (227 words), Passage 3 (357 words) and Passage 4 (522 words). Four questions were created for each passage and the order of the questions remained the same: (1) setting inference, (2) causal-near inference, (3) causal-far inference and (4) elaborative inference. A common scoring system was used and a score of 1 was given for each correct answer. The maximum score for each subset varied according to the number of items in it.

Participants

Children between the ages of 6-13 years studying in grades between I to VIII in a school following the academic curricula proposed by Central Board of Secondary Education (CBSE) were recruited. A total of 160 typically developing children (TDC) from I to VIII grade were taken, 20 children (10 males and 10 females) each from different grades. All participants were typically developing children (TDC), without any speech and language deficits and delayed milestones and with no present/past history of any neurological, psychological problems and/or sensory deficits. Other inclusion criteria required that these children should have been studying in the same school since the beginning of their education and all of them should have had at least average reading achievement in Hindi as well as in English, based on their school records. It was required that participants should not have repeated a grade at any point in their school career, and should have completed all their schooling, thus far in an ordinary school. In addition, their last school report had to indicate at least 60% marks (fourth grade/B2/Good with a grade point of 7) for the language and literacy areas. These criteria were included to avoid the possibility of including children with subtle, previously undetected language disorders. At the time of the present study the children had already spent about six months in a particular grade.

Education in India is provided by the public sector as well as the private sector. Participants were recruited from local Government and Private schools, tuition centres and through personal contacts. Children were divided into two groups according to the medium of instruction in the respective schools: typically developing children who were being educated in a Hindi medium school (TDCH) or typically developing children who were being educated in an English medium school (TDCE). Each group had 80 TDC belonging to grade I to VIII. TDCH children came from Hindi speaking homes with Hindi being their medium of instruction at school also, since the start of their schooling. TDCH were recruited from Government schools under the administration of the Delhi Government. TDCE children came from predominantly Hindi speaking homes with English being their medium of instruction at school since the start of their schooling. TDCE were recruited from Private schools. TDCE were exposed to both Hindi and English since the start of their schooling and were currently spoken on a daily basis. Children who spoke languages other than Hindi and English were not included.

All the schools catered to mixed SES families, but as previous research does predict a predominantly higher SES opting for private education, the two groups of TDCH and TDCE can be to a certain extent assumed to represent a lower and a higher SES respectively. In order to ensure that participants were as homogeneous as possible in terms of socio-demographic variables, schools within the same geographic area in Delhi were selected. In order to control for socioeconomic status to some extent, equal numbers of participants from each group attended government and private schools.

The test was administered on 160 typically developing children (TDC). The children were tested individually in a single 30 minute session in a quiet, noise free environment. The items were presented in a fixed order and an audio video recording of the sessions was carried out.

Results

The descriptive analysis of the data has been dealt with both test section wise as well as grouped according to the medium of instruction.

The Auditory perceptual section of the test had three subsections assessing the auditory identification level (AIL), auditory recall level (ARL) and auditory discrimination (AD). The comparative performance graphs below clearly depict that English medium children' fare better than their Hindi medium counterparts, though the difference in their performance falls as they progress to higher grades. A majority of Hindi medium children achieve full scores on the auditory perceptual subsections by grade III or grade IV, while English medium children achieve this by grade II and in some cases (as in auditory discrimination) in grade I itself.

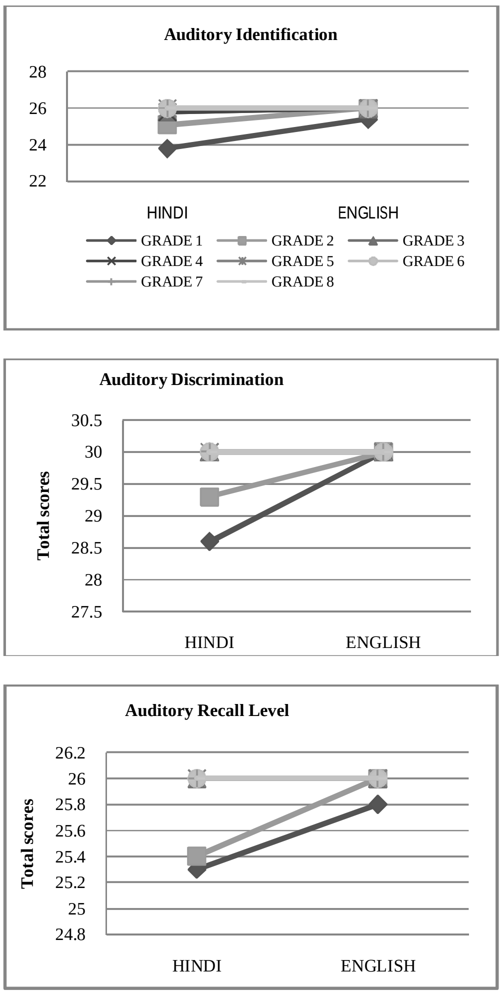


Figure 1: *Auditory Perceptual scores in TDCH & TDCE*

Visual discrimination assessed in two separate levels (level 1 assessing the ability to discriminate differences in forms, size, shape, and orientation; level 2 assessing the ability to discriminate between Hindi alphabets), also showed a similar pattern of better scores by English medium children and achievement of full scores by the primary grade children itself. Overall, till grade IV, all the children scored full on the sections assessing visual discrimination (VD1 & VD2).

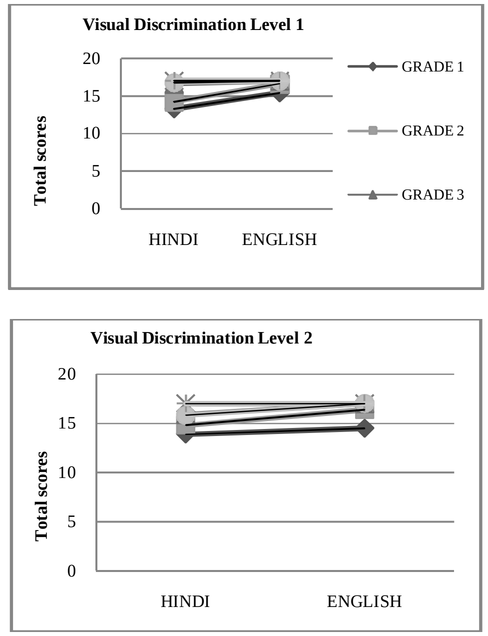
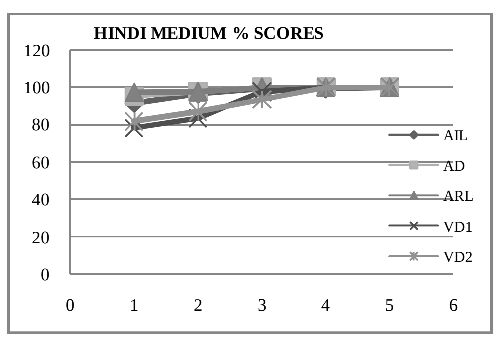


Figure 2: *Visual Perceptual scores in TDCH & TDCE*

The percentage scores were analyzed separately for the Hindi and English medium children, for the first five grades. The Figure 3 clearly depicts that performance is better on the auditory perceptual section as compared to visual perceptual section in all the grades for both the mediums. Among the auditory perceptual section also, the scores increase in the following order: auditory identification < auditory discrimination < auditory recall, till all of them reach the maximum score. In case of English medium children, the auditory recall section had slightly higher scores than auditory discrimination. While visual discrimination level 2 (VD2) was found to have consistently scored better than visual discrimination level 1 (VD1) in the first two grades, the opposite was observed in grade III as well as in English medium children too.



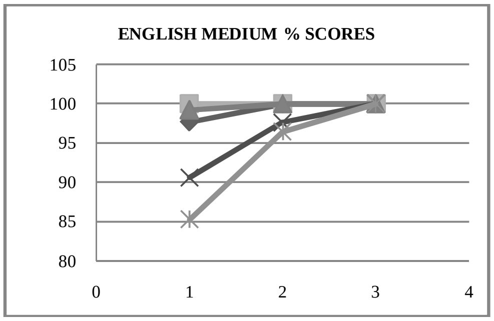


Figure 3: *Perceptual scores in TDCH and TDCE*

The current data set had medium of instruction, grade & gender as independent variables and all the parameters of the test as dependent variables. A multivariate analysis was thus used to analyze it. A p value < .005 indicates that the interaction is statistically significant. MANOVA results indicated that medium of instruction [Wilks' Lambda = .872, F (3, 126) = 6.138, p < .001] and grade significantly affected [Wilks' Lambda =.567, F (21, 362.354) = 3.768, p < .001] the combined dependent variables of the test parameters. There was a statistically significant difference, so further follow up tests were done.

The tests of between-subjects effects revealed that both medium of instruction and grade significantly affected the perceptual parameters of Auditory Identification Level (AIL) and Auditory Discrimination (AD), but Auditory Recall Level (ARL) was affected only by the grade the participant belonged to. Univariate analyses for medium of instruction revealed that AIL and AD was affected in case of both Hindi and English medium of instruction, while ARL was affected in neither group of children. Univariate analyses for the effect of grade revealed that all the auditory perceptual variables of AIL, ARL and AD were significantly affected only in grade I. A further medium v/s grade interaction revealed that this was true in case of Hindi medium of instruction only.

The tests of between-subjects effects revealed that both medium of instruction and grade significantly affected the perceptual parameters of visual discrimination levels one and two (VD1 & VD2). Univariate analyses for medium of instruction revealed that both the visual perceptual tests were affected in case of both Hindi and English medium of instruction. Univariate analyses for the effect of grade revealed that both the visual perceptual tests were significantly affected only in grade I and grade II. A further medium v/s grade interaction revealed that visual perceptual scores were affected in children exposed to English medium of instruction of grade I only while, in children exposed to Hindi medium of instruction, grade I and II both were affected.

Analyses for the combined auditory perceptual tests scores (ARL, AIL and AD) and combined visual perceptual tests scores (VD1 and VD2) revealed both Hindi and English medium of instruction affecting both the perceptual scores; wherein combined auditory perceptual scores (AUD) was affected in grade I and combined visual perceptual scores (VIS) was affected in grade I and II. A further medium v/s grade interaction revealed that in English medium of instruction children, only grade I visual perceptual scores were affected and combined auditory perceptual scores were not significantly affected.

Table 1: *Descriptive & Inferential statistics of TDCE and TDCH*

Dependent Variable		Mean	S.D.	Sig.	F*
Parameter	**Medium**				
AIL	Hindi	25.56	.080	.002	10.194
	English	25.92	.080	.002	
AD	Hindi	29.73	.050	.000	13.569
	English	30.00	.050	.000	
ARL	Hindi	25.83	.037	.010	6.914
	English	25.97	.037	.010	
VD1	Hindi	16.11	.082	.000	29.897
	English	16.75	.082	.000	
VD2	Hindi	16.05	.091	.000	19.014
	English	16.61	.091	.000	
AUD	Hindi	81.13	.131	.000	-
	English	81.90	.131	.000	
VIS	Hindi	32.16	.136	.000	-
	English	33.36	.136	.000	

**The F tests are the effect of medium*

Paired sample tests were performed on the data set separated according to the medium of instruction as well as each grade wise. In case of grade I, except for the pair between visual perceptual composite score and phoneme grapheme correspondence test (Correlation=-.377; Sig. =.283) significance existed in all the pairs of perceptual and reading related skill tests but none of the correlations was statistically significant. This was same for both the medium of instruction children. In case of grade II, while correlations were statistically insignificant, significance existed in all the pairs of perceptual and reading related skill tests, except for the pair between visual perceptual composite score and phoneme grapheme correspondence test (Correlation=-.153; Sig. =.673) in case of Hindi medium of instruction children only. In case of grade III, the correlation between auditory perceptual composite score and structural analysis test score (Correlation=0.859; Sig. =.001) was found statistically significant only for Hindi medium children, while in case of the paired test comparisons, significance existed in all the pairs of perceptual and reading related skill tests. In case of grade IV, while none of the correlations were significant, significance existed in all the pairs of perceptual and reading related skill tests. In grade V, while in case of Hindi medium of instruction children' scores, significance existed in all the pairs of perceptual and reading related skill tests, but in case of English medium of instruction children' scores, the significance didn't exist only between the pair of composite perceptual scores and phoneme grapheme correspondence test (Sig. =.185). A similar pattern was found in grade VI English medium children also, while even in Hindi medium children, the significance didn't exist only in the pair of visual composite perceptual scores and phoneme grapheme correspondence test (Sig. =.114). Hindi medium grade VII children' scores again showed significance in all the pairs of perceptual and reading related skill tests, while in English medium children', the significance didn't exist in the pairs of composite perceptual scores and phoneme grapheme correspondence test (Sig. =.052) as well as the pair of composite perceptual scores and reading passage scores (Sig. =.087). Finally grade VIII English medium children showed a similar pattern of performance to their grade VII counterparts, but in Hindi medium children the significance didn't exist in the pair of composite perceptual scores and phoneme grapheme correspondence test (level 1 and level 2).

Discussion

This study was designed to study the relation between perceptual abilities and reading related skills. Analyses revealed that data set was homogeneous in the pattern of acquisition of perceptual skills, i.e. the scores on both auditory and visual perceptual sections were poorest in the primary grades, showed a steady increase and finally achieved full scores by around grade IV. But the English medium children were found to have better scores on all the sections of perceptual skills. A study examining skills related to reading in preschoolers from diverse linguistic backgrounds (Chiappe, Siegel, & Gottardo, 2002); found that the acquisition of basic literacy skills developed in a similar manner. In this present study, the differences between the medium of instruction may be considered as being an effect of the relatively poorer socioeconomic status (SES) of the Hindi medium children. Children from lower SES develop academic skills more slowly compared to children from higher SES (Morgan, Farkas, Hillemeier, & Maczuga, 2009). This explains difference observed across all the perceptual parameters, with English medium higher SES children scoring full on the tests approximately two grades earlier than their Hindi medium counterparts. But all these differences level out in higher grades, at least with respect to perceptual abilities. Molfese, Molfese, and Modglin (2003) concluded that SES was consistently correlated with reading achievement of children of ages 3 to 10. Children from low-SES environments were found to be slower in acquiring language skills, exhibited delayed letter recognition and phonological awareness, and were at a greater risk of reading difficulties (Aikens & Barbarin, 2008). School attended by low-SES communities are often under resourced, which negatively affects students' academic progress (Aikens & Barbarin, 2008). Thus, even the effect of difference of schooling (government and private) existing between the two data groups cannot be undermined.

While gender was found to be a non significant variable, medium of instruction was found to be insignificant only in case of the auditory recall test. Study by Douglas and Montiel (2008) illustrated that poor children begin school with lower skills than wealthier children in recognizing letters, and knowledge of sounds at the beginning and ending of words. But almost all of the children master letter recognition by first grade, while knowledge of sounds at the beginning and ending of words (required for auditory discrimination) still showed a lag by poorer SES children till third grade. A similar pattern of interaction of poorer SES (Hindi medium of instruction) was shown only in the primary grades in this study also.

Pasamanick and Knobloch (1958) and Deutsch (1964) found that low SES children manifested a disproportionately high incidence of visual perceptual deficits. These studies are in accordance with the results of this study which also demonstrates an interaction of the Hindi medium of instruction (lower SES) with visual perceptual scores, while this interaction is limited to just the first grade in case of English medium children. Havaei, Gholamian, Rezaei, Fadayi, and Azam's (2009) study had suggested that visual perceptual skills are affected by cultural and educational issues. Thus, the differences in the present study may be the result of a disadvantaged socioeconomic background or even schooling.

Children in all the grades (grade I to grade VIII) in both TDCE and TDCH, showed a statistically significant relation between all the perceptual parameters and reading related skills. Studies in agreement with this relationship between auditory perceptual skills and literacy readiness skills include Marston and Larkin (1979), Elliott, Hammer, and Scholl (1989), and Corriveau, Pasquini, and Goswami (2007). King, Wood, and Faulkner (2007) had concluded that the discrimination of visual stimuli develops concurrently with the development of the alphabetic principle.

Research by Hammill and Larsen (1974) found that auditory perceptual abilities were poorly related to reading and Gupta, Ceci, and Slater (1978) also concluded that visual discrimination abilities were not a factor associated with reading achievement. In the current study also none of the correlations between the perceptual and reading related skills were found to be statistically significant in any of the groups or any grade. Thus, the study is in agreement with the current literature, which states that true hierarchical relationships between auditory and visual perception abilities and reading success is ambiguous (Badian, 2005).

But in this study a statistically significant correlation was observed between auditory perceptual composite score and structural analysis test score. Syntactic awareness is the ability to understand the grammatical structure of a language. Deficits in syntactic awareness have been reported in poor readers of English (Tunmer, Nesdale, & Wright, 1987) and other languages also (So & Siegel, 1997).

Phoneme grapheme correspondence was found to have a statistically non-significant relation with perceptual abilities in this study. An early loss of a statistically significant relationship with visual perceptual skills can be explained by the study by Vellutino (1991) who found that visual abilities were poorly predictive of abilities like, word identification, spelling, pseudo word decoding, and reading comprehension at grade levels II to VII. The data of higher grades reveal a progressive loss of relationship between perceptual skills and reading related skills, further shedding light on the probability that the contributions of basic perceptual skills to reading related skills reduces as child approaches higher grades. The development of reading may thus depend partly only on the development of basic visual perception. The relationship between auditory discrimination and literacy success are also not entirely accepted.

Limitations: The cross-sectional design of this study did not permit the examination of the relationship between perceptual abilities and reading through the course of development. The SES factor could not be accurately measured and hence the relationship between private schools and children's educational outcomes may be spurious. Simultaneously, the effect of constant literacy instruction throughout the course of data collection, impact of home environments related to literacy experiences, instructional differences among teachers, and simply the maturity of the child in the school environment are all factors that were uncontrollable in the present study.

Implications and future directions: The finding that perceptual abilities were related to reading related skills highlights the importance of assessing visual and auditory perceptual abilities in school-age children who demonstrate difficulty in performing educational tasks. Keeping in mind the results of this study may help avoid inaccurate assessment results or clinical reasoning, due to undetected or unsuspected perceptual deficits. The study also throws light on the possible role the medium of instruction and SES plays in perceptual skill development and the strength of its relation with reading related skills. If such critical pre-reading skills are evaluated and discovered earlier, future reading success can be predicted. On the other hand, regarding the decrease of contribution of perceptual skills in higher educational levels and older ages, it is suggested to pay more attention on the effect of other reading related skills on academic performance. These results can be thus used in planning appropriate management strategies for Hindi speaking children with reading deficits.

Data gathered from this study generated several directions for future research. The confounded impact of age, instruction, parental involvement, exposure to reading materials, social-cultural context, early intervention and other similar factors on reading level are ambiguous relationships, which need to be explored. Research studies aimed at examining the burgeoning of language and how language and perception mediates the development of reading in the early school years should be a future research goal.

Conclusions

These results, along with the literature support, emphasize that there are complex patterns between cause and effect in the area of reading and its related skills because learning to read involves many cognitive processes and a breakdown in any one of these may affect ability to read. The results of this study also suggest that a perceptual deficit may hinder reading development in the elementary grades, but in higher grades a more complex interrelation of perceptual and reading related skills exists.

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References

Aikens, N. L., & Barbarin, O. (2008). Socioeconomic differences in reading trajectories: The contribution of family, neighborhood, and school contexts. *Journal of Educational Psychology,* 100(2), 235−251.

Badian, N. (2005) Does a visual-orthographic deficit contribute to reading disability? *Annals of Dyslexia*, 55, 28-52.

Bretherton, L., & Holmes, V. M. (2003). The relationship between auditory temporal processing, phonemic awareness, and reading disability. *Journal of Experimental Child Psychology*, 84, 218-243.

Bruininks, R. H. (1968). Relationship of auditory and visual perceptual strengths to methods of teaching word recognition among disadvantaged Negro boys. *IMRID Behavioral Science Monograph,* George Peabody College, No.12.

Bruininks, R. H. (*1969).* Auditory and visual perceptual skills related to the reading performance of disadvantaged boys. *Perceptual and Motor Skills*, 29, 179-186.

Burrows, E. H. & Neyland, D. (1978). Reading skills, auditory comprehension of language, and academic achievement. *Journal of Speech and Hearing Disorders*, 43(4), 467-472.

Cestnick L. (2001). Cross-modality temporal processing in developmental phonological dyslexics. *Brain and Cognition*, 46(3), August, 319-325.

Cestnick L., & Jerger J. (2000). Auditory temporal processing and lexical/nonlexical reading in developmental dyslexics. *J Am Acad Audiol.* 11, 501-513.

Chiappe, P., Siegel, L. S., & Gottardo, A. (2002). Reading-related skills in kindergartners from diverse linguistic backgrounds. *Applied Psycholinguistics*, 23, 95–116.

Clark, A. D., & Richards, C. J. (1966). Auditory Discrimination Among Economically Disadvantaged And Nondisadvantaged Preschool Children. *Exceptional Children,* 33, 259-262.

Corriveau, K., Pasquini, E., & Goswami, U. (2007). Basic auditory processing skills and specific language impairment: a new look at an old hypothesis. *Journal of Speech, Language, and Hearing Research*, 50, 647-666.

Covington, M. V. (1962). Some effects of stimulus familiarization on discrimination. Unpublished doctoral dissertation, University of California.

Deutschc, P. (1964). Auditory discrimination and learning: social factors. *Merrill-Palmer Quarierly*, 10, 277-296.

Douglas, K., Montiel, E., Learning to read in American elementary school classrooms: Poverty and the acquisition of reading skills (2008) Status of Reading Instruction Institute, http://www.reading.org/downloads/resources/ECLSK%20SES%20Report.pdf, Retrieved from, Newark, DE: International Reading Association.

Elliott, L. L., Hammer, M. A., & Scholl, M. E. (1989). Fine grained Auditory Discrimination In Normal Children And Children With Language-Learning Problems. *Journal Of Speech And Hearing Research,* 32, 112-119.

Emerald V. Dechant, Henry P. Smith (1961). Psychology in Teaching Reading. Englewood Cliffs, NJ. Prentice Hall

Fazio, B. B. (1997). Learning a new poem: Memory for connected speech and phonological awareness in low-income children with and without specific language impairment. *Journal of Speech, Language, and Hearing Research,* 40, 1285–1297.

Fletcher J.M., Shaywitz, S.E., Shankweiler, D.P., Katz, L., Liberman, I.Y., Stuebing, K.K., & Shaywitz, B.A. (1999). Co-morbidity of learning and attention disorders: Separate but equal. *Pediatric Clinics of North America*, 46, 885–897.

Frost, R. (1998). Toward a strong phonological theory of visual word recognition: True issues and false trails. *Psychological Bulletin*, 123, 71–99.

Gardner, R. C. (1985). Social Psychology and Second Language Learning: The Role of Attitudes and Motivation. London, GB: Edward Arnold.

Getman, G.N. (1984). How to Develop Your Child's Intelligence; Research Publications, California.

Gupta, R., Ceci, S. J., Slater, A.M. (*1978*). Visual-Discrimination in Good and Poor Readers. *Journal Special Education*, 12(4), 409-416.

Hammill, D .D. & Larsen, S. C. (1974). The Relationship of Selected Auditory Perceptual Skills and Reading Ability. *Journal of Learning Disabilities*, 1(7), 429-434.

Havaei, N., Gholamian, H. R., Rezaei, M., Fadayi, F., & Azam, K. (2009). Study of Visual Perceptual Skills in Normal School Students Aged 11 to 13 Years in Tehran City by TVPS-R. *Medical Journal of Tabriz University of Medical Health Sciences and Health*, 6, 31-36.

Kavale, K.A. *(*1981*)*. The relationship between auditory perceptual skills and reading ability: A meta-analysis. *Journal of Learning Disabilities*, 14, 539–546.

Kavale, K. (1982). Meta-analysis of the relationship between visual perceptual skills and reading achievement. *Journal of Learning Disabilities*, 15 (1), 42–51.

King, B., Wood, C. & Faulkner, D. (2007). Sensitivity to auditory and visual stimuli during early reading development. *Journal of Research in Reading*, 30(4), pp. 443–453.

Marston, L.E., & Larkin, M. (1979). Auditory assessment of reading underachieving children. *Language, Speech and Hearing Services in the Schools*, 10(4), 212-220

Mcconnell, F., & Robertson, B. (1967). Auditory Perceptual Skills of Culturally Disadvantaged Children. *Paper Presented At The Sixth International Congress Of Phonetic Sciences, Prague*, The Czechoslovak Socialist Republic.

Molfese, V.J., Modglin, A.A. & Molfese, D.L. (2003). Newborn and preschool predictors of second-grade reading scores: An evaluation of categorical and continuous scores. *Journal of Learning Disabilities*, 34, 545–554.

Moore, C. M. (1996). Does negative priming imply pre-selective identification of irrelevant stimuli? *Psychonomic Bulletin & Review, 3*, 91-94.

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2009). Risk factors for learning-related behavior problems at 24 months of age: Population-based estimates. *Journal of Abnormal Child Psychology,* 37*, 401-413*.

Neville D., *&* Bruininks R. H. (in press). Reading and intelligence. In Haywood H. C. (Ed. J, Psychometric intelligence. New York: Appleton-Century-Crofts.

Olson, R.K. & Datta, H. (2002). Visual-temporal processing in reading-disabled and normal twins. *Reading and Writing*, 15, 127-149.

Pammer, K., & Kevan, A. (2007). The contribution of visual sensitivity, phonological processing, and nonverbal IQ to children's reading. *Scientific Studies of Reading*, 11, 33-53.

Pasamanick*, B.,* & Knobloch*, H.* (*1958*). The contribution of some organic factors to school retardation in Negro children. *Journal of Negro Education*, 27, 4–9.

Rae, G. & Potter, T. (1973). Informal reading diagnosis: A practical guide for the classroom teacher. Prentice-Hall (Englewood Cliffs, N.J)

Rosner J. (1972). The development and validation of an individualized perceptual skills curriculum. *Learning Research and Development Center*, University of Pittsburgh, Pittsburgh.

Rosner J. (1974). Auditory analysis training with prereaders. *The Reading Teacher*, 27:379-84.

Rosner J. (1975). Helping Children Overcome Learning Disabilities. New York: Walker & Company.

Samuels, S. J., & Anderson, R. H. (1973). Visual recognition memory, paired-associate learning, and reading achievement. *Journal of Educational Psychology*, *65*, 160-167.

Slaughter, J. P. (1983). Big books for little kids: Another fad or a new approach for teaching beginning reading? *The Reading Teacher*, 36, 758-763.

So, D., & Siegel, L.S. (1997). Learning to read Chinese: semantic, syntactic, phonological and working memory skills in normally achieving and poor Chinese readers. *Reading and Writing*, 9, 1–21.

Sterritt, G.M., & Rudnick, M. (1966). Auditory and visual rhythm perception in relation to reading ability in fourth grade boys. *Perceptual and Motor Skills*. 22, 859-864.

Tunmer, W.E., Nesdale, A.R. and Wright, A.D. (1987). Syntactic awareness and reading acquisition. *British Journal of Developmental Psychology*, 5, 25-34.

Vellutino, F.R. (1991). Introduction to three studies on reading acquisition: Convergent findings on theoretical foundations of code-oriented versus whole-language approaches to reading instruction. *Journal of Educational Psychology*, 83, 437–443.

Watson, B. U. & Miller, T. K. (1993). Auditory perception, phonological processing, and reading ability/disability. *Journal of Speech and Hearing Research*, 36, 850-863.

Whisler, Nancy G. (1974). Visual-memory training in first grade: Effects on visual discrimination and reading ability. *The Elementary School Journal*, 75, 50-54.

CERVICAL VESTIBULAR EVOKED MYOGENIC POTENTIALS: A REVIEW

[1]Vinni Chhabra, & [2]Sujit Kumar Sinha

Abstract

Vestibular evoked myogenic potential is a recent tool to assess the sacullocollic pathway. The sacullocollic pathway includes the saccule, the vestibular nuclei and the medial vestibulo spinal tract. In the literature the studies done on vestibular evoked myogenic potentials have used different recording protocols. Various databases such as Medline, Pubmed, Google and Google scholar were searched for the references related to the vestibular evoked myogenic potentials. The different recording procedures from the literature have been summarized in the present article.

Key Words*: Vestibular evoked myogenic potentials, Click, Tone burst, Muscle tension*

Vestibular evoked myogenic potentials (VEMPs) were first described by Bickford, Jacobson, and Cody (1964), and have been suggested as a trustworthy clinical test to evaluate the functioning of saccular or inferior vestibular nerve (Cloebatch, 2001). VEMPs are electromyogram (EMG) with short latency and are evoked by higher-level acoustic stimuli. .Surface electrodes placed over the tonically contracted sternocleidomastiod (SCM) muscle elicit VEMPs. According to the neurophysiological and clinical data, VEMP pathway includes the saccular macula, inferior vestibular nerve, the medial vestibular nucleus, the medial vestibulospinal tract, and the motorneurons of the ipsilateral SCM muscle (Halmagyi & Curthoys, 2000).

Short latency responses to auditory clicks at the inion recorded by Geisler, Frishkopf, and Rosenblith (1958) recorded were initially considered to be cortical in origin. Later, Bickford, Jacobson, and Cody (1964) described the characteristics of these responses and ascertained their vestibular origin. Cody and Bickford (1969), and Townsend and Cody (1971) provided further evidence suggesting the mediation of these responses from the vestibular end organ, specifically the saccule.

In 1994, Colebatch, Halmagyi, and Skuse established a reliable procedure to record the myogenic potentials evoked by the clicks. These authors modified the previous recording procedures by incorporating the placement of surface electrodes on the sternocleidomastoid (SCM) muscles. Normal VEMP responses are characterized by biphasic (positive – negative) waves. In a majority of studies, labelling of the peaks and troughs is done with the lower case letters ‘ p’ (for positive) or ‘ n ‘ (for negative) followed by the mean latency in milliseconds (Yoshie and Okodaira, 1969). This is done to distinguish them from neurally generated evoked potentials. The first positive- negative complex is often labeled as p13-n23. A second wave complex (n34-p44) has also been reported to be present in 68% of the participants (Robertson and Ireland, 1995). Figure -1 shows the waveform obtained for the Vestibular evoked myogenic potentials from a normal hearing individual.

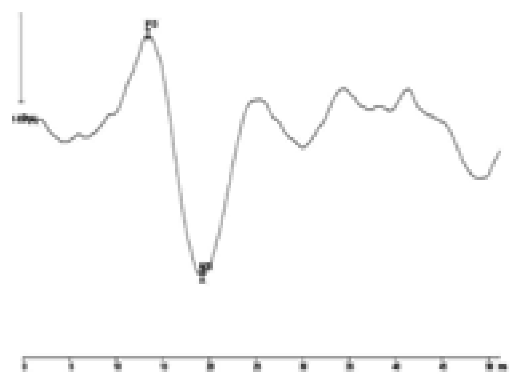

Figure-1: *Typical waveform obtained for Vestibular evoked myogenic potentials*

***VEMPs Analysis Strategies*:** Record optimal response from each side. Calculate P1 latency, N1 latency and P1 —N1 amplitude. Compare the normative data to that of the patient data. It is very important to calculate inter aural amplitude of P1-N1 complex. The calculation of interaural amplitude is an important parameter in unilateral vestibular lesions. The interaural amplitude parameter is calculated as:

- Amplitude Ratio (%) = (AL-AR)/ (AL+AR) X 100, where L= left ear, R= right ear

The amplitude ratio is considered to be normal if it is less than 0.35, and if greater than 0.35, it is considered to be abnormal.

[1]Student, All India Institute of Speech and Hearing (AIISH), Mysore-06, E-mail: vinni.aiish@gmail.com & [2]Lecturer in Audiology, AIISH, Mysore-06, Email: sujitks5@gmail.com

Need for the present review: In the literature, there are few review articles on VEMP (Ferber-Viart, Dubreuil, & Duclaux, 1999; Welgampola & Colebatch, 2005; Rausch, 2006; Honaler & Samy, 2007; Renato & Fayez, 2009; Mudduwa, Kara, Whelan & Banerjee, 2010; Eleftheriadou & Koudounarakis, 2010) none of which explain the method of recording procedure, stimulus variability, and stimulus parameters in greater detail. An attempt is to review these articles on the method of recording procedure and other stimulus parameters in greater detail for the benefit of the readers.

ROADMAP of the review:
Recording protocol:
Methods of recording
Type of stimuli
Intensity
Monaural and binaural stimulation
Stimulus polarity
Presentation rate
Transducer

1. **Methods of recording Vestibular Evoked Myogenic Potentials:** There are four methods by which the vestibular evoked myogenic potentials are recorded:
a. Air Conducted VEMP
b. Bone Conducted VEMP
c. Skull Taps
d. Galvanic Stimulus

1. a. Air conducted *VEMP:* Intense clicks of about 95 to 100 dB nHL are required to evoke VEMPs and are at the limit of what is considered generally well tolerated, However, an uncomfortable level should be elicited from the client before undergoing this test.. Stimuli of 95 db NHL and 0.1-millisecond duration are used in routine clinical tests performed.

1. b. Bone conduction VEMP: Bone-conducted tones bypass the middle ear conductive apparatus and can evoke VEMPs inspite of conductive hearing loss.

1. c. Skull Taps: A forehead tap, delivered at Fpz (International 10–20 System) via a tendon hammer, evokes a vestibular dependent short-latency p1n1 response in both sternocleido mastoid muscles. The technique is operator dependent and does not deliver a calibrated stimulus. VEMp elicited by the skull taps are generally 1.5 to 3 times larger compared to the air conducted VEMP elicited through head phones or insert ear phones.

1. d. Galvanic VEMP: A short-duration (2-millisecond) pulsed current delivered via electrodes attached to the mastoid processes evokes a p13n23 response on the side ipsilateral to cathodal stimulation similar to that evoked by sound. Galvanic VEMP is a retro labyrinthine response, which actually bypasses the peripheral structures and it stimulates the vestibular nerves directly. A combination of galvanic and air conducted VEMP can indicate whether the lesion is in the peripheral structure or in the vestibular nerve.

2. **Stimulus type:** Clicks, short duration tone bursts and logons have been used as stimulus both monaurally and binaurally to obtain VEMP recordings.

A. **Clicks:** The different parameters for click stimuli that have been investigated are as follows:
- Duration
- Repetition rate

Duration of click stimuli*:* Click stimuli with different durations have been used to record VEMP. Studies have revealed that longer duration gives better response rate but latencies are prolonged for longer duration clicks. A study by Huang; Su & Cheng, 2005 indicates that click duration of 0.2, 0.5 and 1.0 ms gives a 100% response rate, compared to 0.1 ms. Increase in the click duration from 0.1 to 1 ms lead to prolongation of p13 and n23 latencies respectively. This prolongation was attributed to longer duration of stimulus. Highest amplitude was seen for 0.5 and 1.0 VEMPs which decreased with decrease in duration of click. Since the smallest interaural latency difference was obtained with 0.5 VEMP and lesser sound energy exposure is required for 0.5 VEMP compared to 1.0 VEMP, 0.5 VEMP is recommended to be the optimum duration for VEMP elicitation (Cheng, et al., 2005).

Repetition rate: In a study by Wu and Murofushi (1999), VEMP recordings with repetition rate of 1Hz, 5 Hz, 15 Hz and 20 Hz were compared and the results revealed that VEMPs for 1 Hz and 5 Hz stimuli showed the highest amplitude which tends to decrease as repetition rate increases. Variance in measurement of latencies was reported to be largest with 20 Hz and smallest with 1Hz but with 1Hz stimuli neck muscles had to be contracted for longer. Hence, 5 Hz is considered to be the optimal stimulation rate for the clinical use of VEMP (Wu, et al., 1999).

B. **Short duration tone bursts:** Better VEMP responses are expected using low frequency tone bursts and logons, which can be attributed to high sensitivity of single afferent saccular nerve fibre to low frequency acoustic stimulus as indicated in various animal studies (McCue and Guinan, 1994; Murofushi et al, 1995). The tone-burst-evoked responses showed no latency effect whereas the amplitude was largest when 500 and 1000 Hz tone bursts were used compared to higher frequency tone bursts (Welgampola and Colebatch, 2001).

Different parameters that have been studied using tone bursts are as given below:

- Plateau time
- Rise/fall time
- Frequency of the stimulus

Rise/fall time: Studies reveal that latencies are prolonged with increase in rise/fall time keeping the plateau time constant at 2 ms. When rise/fall time of 0.3ms, 1ms, 3ms and 10ms were compared, it was found that rise/fall time of 1 ms produced the largest amplitude compared to 0.3, 3 and 10 ms. The amplitude drops drastically if 10 ms rise/fall time is used (Cheng and Murofashi 2001). Hence 500Hz of STB frequency having rise/fall time of 1ms with plateau of 2ms was concluded to be the optimal stimulation pattern as the waveform morphology obtained with this combination was most constant and marked.

Plateau time: Cheng and Murofashi (2001) studied the effect of different plateau times on the tone burst evoked VEMPs. They found that any plateau time (1ms, 2ms, 5ms or 10ms) is sufficient enough to elicit VEMPs but the latency of P1 and N1 increased with increase in the plateau time; further the peak to peak amplitude was smallest at 1 ms. Reduced peak to peak amplitude was observed if 10 ms plateau time is used and could be as a result of stapedial reflex.

Frequency of the stimulus: Generally, VEMP has been recorded using 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz tone burst frequencies. The responses elicited using the 500 Hz tone burst are generally larger compared to the other frequencies. The larger amplitude of the VEMP with 500 Hz tone burst has been attributed to the band-pass tuning of utricle which is best at 400 and 800Hz (Todd,2009) and band pass tuning of saccule which responds to a well-defined frequency tuning of 300 to 350 Hz (Todd,2000).

C. ***Logon:*** Recently, logon has also been considered as a stimulus to evoke VEMP. Logon is a pure tone, amplitude modulated by a Gaussian function; and has been considered as the best compromise between a rectangular wave and a continuous pure tone (Davis, 1976). Trivelli, Vicini, Ascanio, Greco & Salvinelli (2007) found that logon evoked VEMP presented a P1 latency of 15.58 ms, N1 latency of 26.12 ms, P1N1 interval of 10.54 ms and P1N1 amplitude of 129.27 μV.

Comparison of VEMP responses elicited by Click, Tone burst and Logon stimulus:

Click vs. tone bursts: Akin, Murnane and Proffitt (2003) reported that although the amplitude of response increased as a function of both clicks and tone burst level, the tone burst evoked VEMP amplitudes were larger than click-evoked amplitudes when compared at equal peak SPLs. As the tone burst frequency decreased, the amount of amplitude differences between tone-evoked and click evoked VEMPs increased. Their study also revealed that 500 Hz and 750 Hz tone bursts produced more robust responses compared to clicks. In a recent study by Kumar, et al. (2011), VEMP recordings were obtained with shorter latencies using click stimuli compared to tone bursts but the amplitude of responses was greater in a tone burst evoked VEMP. Hence, click stimuli may be more beneficial than short duration tone burst for clinical identification of abnormality due to its lesser variability whereas, tone bursts would be a better choice while assessing the presence and absence of VEMP responses.

Click vs. logon: Trivelli, et al., (2007) compared clicks and logon as a stimulus to evoke VEMP and found that there was a significantly higher P1/N1 amplitude in comparison with click evoked VEMP for both air and bone-conducted stimuli. The study also revealed that lesser intensity of logon is needed to evoke VEMP responses as compared to click and that logon evokes larger and more robust VEMP responses.

3. **Stimulus intensity:** Like other parameters, stimulus intensity also has an effect on VEMP response amplitudes. A common reason reported for failing to obtain robust responses is inadequate stimulus intensity (Akin & Murnane, 2001; Colebatch, 2001). Few studies have reported the intensity in terms of sound pressure level whereas others in normalized hearing level (nHL). The use of different decibel reference units can be a cause of confusion clinically, as most of the equipment are calibrated for the clicks and/or tone bursts using different decibel scales (Colebatch, 2001). Lowest intensity at which repeatable VEMP waveforms can be obtained is termed as VEMP threshold which lies between the range of 80dBnHL to 100dBnHL with a mean of 91dBnHL (Akin, et al., 2003).

4. **Monaural or binaural stimulation:** VEMP has been recorded using monoaural and binaural stimulation. VEMP using the monoaural stimulation method with ipsilateral recording is considered to be a more reliable technique that provides the closest to normal p13–n23 amplitudes and p13 and n23 latencies (Eleftheriadou, et al., 2008). Wang and Young (2003) recorded VEMP using a binaural stimulation. Wang and Young (2003) reported that there was no difference in the latencies of p13 and n23 with binaural or monoaural stimulation. However, the relative amplitude of binaural VEMP was reduced compared to the monoaural stimulation. Although, the monoaural recording of VEMP is considered to be more reliable, it has a major disadvantage. This method requires a sufficient level of muscle tension from the clients, which may not be feasible in the elderly or very young clients. Thus, in this group of clients, VEMP can be recorded using a binaural stimulation rather than monoaural stimulation, which would require less muscular effort, providing similar information as that of monoaural stimulation of VEMP.

5. **Electrode montage:** Back in 1969, Cody and Bickford measured vestibular responses from inion with reference electrode on the nose or earlobe and inverting electrode on the forehead; but this montage, did not elicit responses from all normal individuals. Viart, Duclaux, Colleaux and Dubreuil (1997) compared VEMP responses from sternomastoid and trapezius muscles. With reference electrodes in the middle of the anterior edge of the clavicles and a medial frontal electrode as ground, Ag/AgC1 surface electrodes placed over the SM halfway between the mastoid and clavicle evoked shorter latencies and lower amplitude responses compared to the trapezius muscles placement irrespective of type of stimulation. .

Colebatch, (2001) modified the montage with active electrode on the upper third of the SCM muscle, and the reference electrode on the muscle tendon just above the sternum. This montage elicited repeatable p13-n23 waveforms from all participants. Sheykholeslami, Murofushi, and Kaga (2001) recommended recording from the middle part of SCM as it provided the most consistent results.

Rudisill and Hain, (2008) recorded lower extremity myogenic potentials from gastrocnemius with noninverting electrodes placed on the right and left gastrocnemius; inverting electrodes, on the right and left medial malleolus; and the ground electrode, on the right or left lateral malleolus. Both ipsilateral and contralateral responses to acoustic stimulus were obtained with gastrocnemies placement. Responses were in the form of biphasic waves with P1-N1 and P2-N2 but not all subjects showed both components. When compared to the SCM placement, responses were smaller and later with P2-N2 being the most reliable wave. The responses were compared to the responses from SCM and the results revealed that responses were obtained in the gastrocnemius, both ipsilateral and contralateral to the acoustic stimulus. The response consisted of 2 biphasic waves (P1-N1 and P2-N2), although not all subjects exhibited both components. The most reliable wave was P2-N2 and the responses were smaller and later than those in the SCM.

To obtain the effect of different head positions on VEMP, recordings have been obtained with a surface electrode placement on the upper half of the left sternocleidomastoid muscle (SCM), a reference electrode on the medial end of the left clavicle and a ground electrode on the nasion (Ito, Karino, & Murofushi,2007).

6. **Effect of muscle tension on Vestibular evoked Myogenic potentials:** Muscle tension is an important factor in recording the Vestibular evoked. Myogenic potentials from the sternocleido mastoid muscles (SCM). As the muscle tension increases, the amplitude of the VEMP increases drastically. Therefore, it becomes very important to monitor the muscle tension during the recording of the VEMP from SCM. Based on the monitoring of muscle tension, there are two methods of recording-rectified and un-rectified methods of VEMP. In un-rectified method, a task is being given to move the neck up to a certain position but there is no monitoring of the EMG activity, whereas, in the rectified method, an EMG device monitors the activity of the muscles during the whole recording. Akin et.al (2003) recorded VEMP with both click and tone burst stimuli in nineteen individuals using rectified method and evaluated intensity and frequency effects. These subjects were given visual feedback of EMG in order to maintain tonic EMG at 50 mV during the testing. The authors hence concluded that the differences in VEMP amplitude were presumably due to the intensity and frequency and not due to the variations in EMG level. However, in another study by Bush, Jones and Shinn (2010), no significant effect on amplitude asymmetry was found with presence or absence of muscle tension monitoring.

Conclusions

The present review provided information on different recording procedures that have been used in order to obtain VEMP responses. The effect of different recording parameters on VEMP responses has also been discussed. Hence, all the above mentioned factors should be taken into consideration before choosing the appropriate protocol for VEMP recording.

References

Akin, F.W., Murnane, O.D., & Proffitt, T.M. (2003). The Effects of Click and Tone-Burst Stimulus Parameters on the Vestibular Evoked Myogenic Potential (VEMP). *Journal of the American Academy of Audiology,* 14 (9), 500-509.

Bickford, R.G., Jacobson, J.L & Cody, D.R. (1964). Nature of average evoked potentials to sound and other stimuli in man. *Annals of the New York Academy of Sciences*. 112, Sensory Evoked Response in Man, 204–218.

Bush, M.L; Jones, R.O; & Shinn, J.B. (2010). The clinical reliability of vestibular evoked myogenic potentials. *Ear Nose Throat Journal,* Apr, 89, (4), 170-176.

Cal, R; & Bahmad, F. (2009). Vestibular evoked myogenic potentials: an overview. *Brazilian Journal of Otorhinolaryngology,* 75, 456-462.

Cheng, P.W., & Murofashi, T. (2001). The Effect of Rise/ Fall Time on Vestibular-evoked Myogenic Potential Triggered by Short Tone Bursts. *Acta Otolaryngologica,* 121: 696–699.

Cheng, P.W., & Murofashi, T. (2001). The effects of Plateau Time on Vestibular evoked Myogenic Potentials triggered by Tone Bursts. *Acta Otolaryngologica*, 121, 935-938.

Colebatch, J.C, Halmagyi, G.M., & Skuse, N.F. (1994). Myogenic potentials generated by a click-evoked vestibulocollic reflex. *Journal of Neurology Neurosurgery & Psychiatry,* 57, 190–197.

Colebatch, J.C. (2001). Vestibular evoked potentials. *Current Opinion in Neurology*, 14, 21–26.

Curthoys, I.S., Kim, J., McPhedran, S.K., & Camp, A.J. (2006). Bone conducted vibration selectively activates irregular primary otolithic vestibular neurons in the guinea pig. *Experimental Brain Research*, 175(2), 256-67.

Davis H. Principles of electric response audiometry. *Annals of Otology Rhinology and Laryngology*, 85, 1-19.

Driscoll, C., Bekessy. A., Bui. V., Fox, D., & Harvey, M. (2007). Vestibular Evoked Myogenic Potentials: Clinical Implications of a Normative Investigation. *The Australian and New Zealand Journal of Audiology,* 29 (2), 98–112.

Eleftheriadou, A. et al. (2008) Vestibular evoked myogenic potential eliciting in normal subjects: subjects: Comparison of four different methods. *Journal of Otolaryngology-Head & Neck Surgery*, 37 (5), 704 - 711.

Ferber-Viart, C., Duclaux. R., Colleaux, B., & Dubreuil C. (1997). Myogenic vestibular-evoked potentials in normal subjects: a comparison between responses obtained from sternomastoid and trapezius muscles. *Acta Otolaryngologica*, 117(4), 472-481.

Geisler, C.D., Frishkopf, L.S., & Rosenblith, W.A. (1958) Extracranial responses to acoustic clicks in man. *Science,* 128, 1210-1215.

Halmagyi GM, Curthoys I. (2000). Otolith function tests. In: Herdman SJ, ed. Vestibular Rehabilitation. Philadelphia: F.A. Davis, 196–214.

Huang T.W, Su H.C, & Cheng, P.O. (2005). Effect of click duration on vestibular-evoked myogenic potentials. *Acta Oto-Laryngologica*, 125, 141-144.

Ito, K., Karino, S., & Murofushi T. (2007). Effect of head position on vestibular evoked myogenic potentials with tone burst stimuli. *Acta Otolaryngologica*, 127(1), 57-61.

Kumar, K., Sinha, S.K., Bharti, A.K., & Barman, A. (2011). Comparison of vestibular evoked myogenic potentials elicited by click and short duration tone burst stimuli. The Journal of Laryngology & Otology, 125, 343–347.

McCue, M.P., & Guinan, J.J. (1994). Acoustically responsive fibers in the vestibular nerve of the cat. *Journal of Neuroscience,* 14, 6058–6070.

Mudduwa, R., Kara, N., Whelan' D., & Banerjee, A. (2010). Vestibular evoked myogenic potentials: review. *The Journal of Laryngology & Otology*, 124, 1043-1050.

Murofushi, T. & Curthoys, I.S. (1997). Physiological and anatomical study of click-sensitive primary vestibular afferents in the guinea pig. *Acta Otolaryngologica,* 117, 66–72.

Rauch, S.D. (2006). Vestibular evoked myogenic potentials. *Current Opinion in Otolaryngology Head and Neck Surgery,* 14(5), 299-304.

Robertson, D. D., & Ireland, D. J. (1995). Vestibular evoked myogenic potentials. *The Journal of Otolaryngologica,* 24, 3-8.

Rudsill, H.E., & Timothy C.H. (2008). Lower Extremity Myogenic Potentials Evoked by Acoustic Stimuli in Healthy Adults. *Otology & Neurotology*, 29, 688-692.

Seo, T., Miyamoto, A., Saka, N., Shimano, K., Nishida. T., Hashimoto. M., & Sakagami, M. (2008).Vestibular evoked myogenic potential induced by bone-conducted stimuli in patients with conductive hearing loss. *Acta Oto-Laryngologica*, 128, 639-643.

Sheykholeslami, K., Murofushi, T., Kermany, M.H., & Kaga, K. (2000). Bone-Conducted Evoked Myogenic Potentials from the Sternocleidomastoid Muscle. *Acta Otolaryngologica,* 120, 731–734.

Townsend, G.L., & Cody, D.T.R. (1971). The averaged inion response evoked by acoustic stimulation: Its relation to the saccule. *Annals of Otology Rhinology & Laryngology,* 80, 121–131

Trivelli, M., Vicini, C., D'ascanio, L., Greco, F., & Salvinelli, F. (2008). The effects of logon versus click on vestibular evoked myogenic potentials. *Acta Oto-Laryngologica*, 128, 314-317.

Wang, S.J. & Young, Y.H. 2003. Vestibular evoked myogenic potentials using simultaneous binaural acoustic stimulation. *Hearing Research*, 185, 43-48.

Welgampola, M.S., Rosengren, S M., Halmagyi, G.M., & Colebatch, J.G. (2003). Vestibular activation by bone conducted sound. *Journal of Neurology Neurosurgery & Psychiatry*, 74, 771–778.

Wempgola, M.S., & Colebatch, J.G. (2005). Characteristics and clinical applications of vestibular-evoked myogenic potentials. *Neurology*, 26, 1682-88.

Wu, C.H., Murofushi, T. (1999). The Effect of Click Repetition Rate on Vestibular Evoked Myogenic Potential. *Acta Otolaryngologica (Stockholm)*, 119, 29–32.

COCHLEAR HYDROPS ANALYSIS MASKING PROCEDURE IN INDIVIDUALS WITH NORMAL HEARING AND MENIERE'S DISEASE

[1]Prawin Kumar, & [2]Pallavi Peepal

Abstract

Meniere's disease (MD) is an idiopathic inner ear disorder which is an abnormal increase in the volume of the cochlear fluid in the inner ear. The diagnosis of MD is always a difficult task. Cochlear hydrops analysis masking procedure (CHAMP) is one of the modified versions of auditory evoked potential test which helps in diagnosing active MD. CHAMP measures changes if any in latency of wave V in auditory brainstem response, caused by the addition of high pass masking noise to the click stimulus ipsilaterally.

There were two groups of participants; control group (33 ears) with mean age 22.2 years and experimental group (30 ears) with mean age of 32.1 years were selected for the study. CHAMP was recorded for both individuals with normal hearing and with MD. The results revealed that the latency of wave V response increased with the lowering of high pass masking noise cut-off from 8 kHz to 0.05 kHz along with click stimuli in both the groups. However, the shift in latency was seen more in the individuals with normal hearing than MD. The probable reason of minimal shifting in latency of wave V in individuals with MD could be due to undermasking phenomena. In the present study, it was observed that if the cut-off latency value to diagnose MD is considered to be 1 msec rather than 0.3 msec, 62.5% normal hearing ears can be separated from MD ears. Similarly, 88.45% MD ears will have abnormal short latency shift which was confirmed the diagnosis of MD. Hence, it can be concluded that this test can be used to distinguish objectively individuals with Meniere's disease with modification in cut-off criteria.

Key words: *Meniere's disease, auditory brainstem response (ABR), Vertigo, Basilar membrane*

Meniere's disease (MD) can be defined as abnormal increase in the volume of the cochlear fluid in the inner ear (Ries, Rickert, & Schlauch, 1999). Further, it is characterized by recurrent, spontaneous episodes of vertigo, fluctuating hearing loss, aural fullness and tinnitus or with a combination of these signs and symptoms fluctuating over months and years (Sajjadi & Paparella, 2008). Histological studies show that etiology of the MD can be linked to Endolymphatic Hydrops (Hallpike & Cairns, 1938; Horner, 1991).

The diagnosis of Meniere's disease has always been a source of confusion. There is no single test that is definitive for the diagnosis. In literature there are several tests that can be performed to distinguish individuals with Meniere's disease from non-Meniere's disease. These are pure tone audiometry, glycerol tests, auditory brainstem response (ABR), and Electrocochleography (ECochG) to assess Meniere's disease. However, not a single test as mention above is having good sensitivity and specificity. Further, only histological findings can help in the confirmation of a Meniere's disease, obtained through post-mortem biopsies Roeser, Valente, Hosford & Dunn, 2000). Therefore, the administration of appropriate clinical diagnostic tools remains a challenging task. Recently, an audiological test developed with modification in auditory brainstem response technique to diagnose active Meniere's disease with better accuracy known as Cochlear hydrops analysis of masking procedure (CHAMP).

CHAMP is a method which consists of measurement in the change of the latency of wave V response in the auditory brainstem response, caused by the addition of high-pass making noise to the click stimulus (Don, Kwong, & Tanaka, 2005). A reasonable assumption in cochlear hydrops is the increase in endolymphatic pressure could increase the stiffness of the basilar membrane. This increased stiffness could increase the speed of travelling wave propagation (Tonnodorf, 1957; Flottorp, 1980). Using ABR latencies obtained with high pass masking noise and assuming a normal frequency place map in the cochlea, Thornton and Ferrell (1991) and Donaldson and Ruth (1996) calculated abnormally high travelling wave velocities in individuals with Meniere's disease. Thus, in individuals with Meniere's disease it is assumed that increased endolymphatic pressure alters basilar membrane's mechanical

[1]Lecturer in Audiology, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: prawin_audio@rediffmail.com, & [2]Clinical Audiologist, Phonak Pvt. Ltd, Delhi.

properties which in terns increase the apparent travelling wave velocity (Don et al., 2005).

Don et al. (2005) studied CHAMP in non-Meniere's normal hearing individuals (mean age 27-29 years) and Meniere's disease individuals (mean age 45-57 years). The results revealed that in Meniere's disease, the masking noise is insufficient for wave V is still present at latency similar to that of wave V in the response to the clicks alone. However, in Non-Meniere's normal hearing individuals, this under masking component was either absent or significantly delays because of the masking noise. They conclude that this test is able to distinguish objectively active Meniere's disease in individuals.

In a similar line, De Valck, Claes, Wuyts and Paul (2007) evaluated the applicability and diagnostic value of CHAMP in a series of Meniere's disease and Non-Meniere's disease individuals. They observed a sensitivity of 31% and a specificity of 28%. Hence, they concluded that CHAMP does not differentiate individuals with Meniere's from Non-Meniere's disease. There was no significant difference between the mean latency difference for Wave V of the Meniere's disease group (0.43 ms) and the Non-Meniere's disease group (0.65 ms). However, when Don et al. (2008) reviewed the data collected in the study by De Valack, et al., (2007) found errors in the data collection that lead to misrepresentation and inappropriate conclusion about CHAMP. Hence, the data were reviewed and analyzed again which increase the sensitivity and specificity to 100% and 80% respectively.

Similar to the finding of Don et al. (2005) were obtained in the study by Singh (2010). The later study was aimed to determine the findings of CHAMP in subjects with suspected & confirmed Meniere's disease & comparing it with the findings of Non-Meniere's disease individuals. The results revealed the an overall specificity of CHAMP to be 76.6% & sensitivity to be 73.8% when the shift in latency of wave V responses for 0.5 KHz high pass masking noise from click alone were measured. This study also yields the shift in latency of wave V increases with successive decreases in high pass masking noise from 8 KHz to 0.5 KHz but the shift was lesser in individuals with Meniere's disease.

The diagnostic value of the CHAMP in terms of sensitivity and specificity in individuals with definite Meniere's disease was assessed by Ordonez-Ordonez et al. (2009). The participants were individuals with normal hearing and with definite Meniere's disease, and other audio-vestibular diseases or neurologic disorders. Results showed Sensitivity and specificity of CHAMP in individuals with definite Meniere's disease were 31.3% and 100% respectively. Based on the above finding, they concluded that CHAMP is more helpful in confirming the diagnosis rather than in rejecting it. If definite Meniere's disease is suspected, an abnormal result confirms the diagnosis. However, a normal result does not rule out the Meniere's disease.

Kingma and Wit (2010) investigated the usefulness of the CHAMP as an additional diagnostic test in individuals with definite unilateral Meniere's disease. Results indicated that latency delays could be measured in both ears. The mean latency delay of wave V responses for the affected ears (0.55 ms) differs significantly from that for the unaffected ears (3.36 ms). These authors considered less than 2 msec as cut-off criteria for latency shift to confirm a diagnosis of Meniere's disease in CHAMP.

From the above literature, it can be construed that there are different views about CHAMP cut-off criteria for the diagnosis of Meniere's disease. There are differences observed in sensitivity and specificity of CHAMP in different studies. Hence, there is need to check the utility of CHAMP in Indian population.

Need for the Study

There are differences in the outcome of CHAMP findings in individuals with Meniere's disease as well as in normal hearing individuals. In recent studies De Valck, et al. (2007) concluded that due to low sensitivity and specificity of CHAMP it cannot be used as a clinical tool to diagnose individual with Meniere's disease. However, other studies oppose these finding and found that CHAMP findings are consistent with the excellent sensitivity and specificity (Don, Kwong, & Tanaka, 2005; Kingma & Wit, 2010; Singh 2010). Hence, there is a need for further study to correctly distinguish individuals with Meniere's disease from normal hearing individuals on the basis of the findings of CHAMP.

Aim of the study

To check the outcome of CHAMP whether it is really a promising tool in diagnosis of individuals with Meniere's disease. Further, to find the diagnostic value of CHAMP in Meniere's disease in relation to normal hearing non-Meniere's disease in Indian population.

Method

The present study was carried out with the aim to study the wave V latency shift in individuals with normal hearing and with Meniere's disease. To conduct the study, the following method was used to record the CHAMP in normal hearing individuals and individuals with Meniere's disease.

Participants

There were two groups of participants, individuals with normal hearing served as control group and individuals with Meniere's disease served as experimental group. In control group, 33 ears (10 females & 7 males) with mean age 22.2 years were selected. However in experimental group, 30 ears (9 females & 8 males) with mean age 32.1 years were selected. The less number of participants in experimental group was because of availability of participants till the completion of data. A detailed case history was taken for each participant in each group. Individuals in both the groups with any neurologic deficit were excluded from the study. Oral consent was taken from all the participants.

Participant selection criteria

In control group, all participants had pure tone thresholds less than 15 dBHL at octave frequencies between 250 Hz to 8000 Hz in both the ears. The overall mean pure tone average was 6.01 dBHL. They had normal middle ear functioning as indicated by Immittance evaluation.

In experimental group, Individuals were having their pure tone thresholds in the range of Mild-to-Moderate (26-55 dBHL) at octave frequencies between 250 Hz to 8000 Hz. The overall mean pure tone average of all individuals was 35.69. They had no indication of middle ear pathology, as per immittance finding. Auditory Brainstem Response and otoacoustic emissions were done on each individual, to rule out retro-cochlear pathology and those individuals indicating retro-cochlear pathology were excluded.

They all had at least 3 of the 4 hallmark symptoms (tinnitus, vertigo, fluctuating hearing loss & fullness) used in the diagnosis of Meniere's disease (Committee on Hearing and Equilibrium, 1995). A detailed case history was taken for each individual and those individuals who fulfilled the above mentioned criteria along with the ENT provisional diagnosis of Meniere's disease were included.

Instrumentation

A calibrated two channel clinical audiometer (OB-922) with TDH-39 headphones and bone vibrator BC-71 was used for pure tone audiometry. A calibrated immittance meter (GSI-TYMPSTAR) was used to assess the middle ear functioning of all the participants. Otodynamic ILO-V6 was used to record transient evoked otoacoustic emissions. Bio-logic Navigator Pro AEP (version 7.0) system was used to record and analyze the waveform of ABR. Bio-logic Broadband inserts earphones were used for CHAMP recording as these inserts have the extended high frequency response needed to acquire valid data for CHAMP Recording.

Test Environment

All the measurement was carried out in an acoustically treated double room situation. The ambient noise level was within the permissible level according to ANSI (1991).

Procedure

All individuals were tested in an acoustically sound treated room with adequate illuminations as per ANSI (1991). Pure tone thresholds were obtained at octave frequencies between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction thresholds.

Tympanometry was carried out with a probe tone frequency of 226 Hz and acoustic reflexes thresholds were measured for 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz ipsilaterally and contralaterally. TEOAEs recording were done using click presented at 70 dBSPL. The probe tip was positioned in the external ear canal and was adjusted to give flat stimulus spectrum across the frequency range. Responses with the reproducibility more than and equal to 80 % was accepted. Click-evoked ABR recording were done to rule out retro-cochlear pathology.

Cochlear Hydrops Analyses Masking Procedure (CHAMP)

For recording CHAMP, individuals were made to relax on reclining chair. The site of electrode placement was prepared with skin preparation gel. Silver chloride (AgCl) electrodes with conducting gel were used for recording CHAMP. The recording electrodes were placed at the upper forehead for non-inverting electrodes and at both mastoid for inverting and ground electrodes respectively. The recorded potential was amplified and band pass filtered at 100 – 3000 Hz. A 16 msec analysis window was used.

Each averaged response was elicited by more than 5000 stimuli repetitions; each condition was repeated once, yielding test and re-test traces. The stimuli were presented monaurally through broadband insert earphones. It was ensured that impedance for each electrode was less than 5 kΩ.

CHAMP responses were obtained to 6 stimulus conditions i.e. clicks presented alone and clicks presented with ipsilateral high pass noise filtered at 8000, 4000, 2000, 1000, & 500 Hz. Hence, there were minimum 12 recording done for one ear (click alone, click + 8000 Hz HPM, click + 4000 Hz HPM, click + 2000 Hz HPM, click + 1000 Hz HPM & click + 500 Hz HPM). To check reliability minimum two times recording were done at each stimulus condition. The broad band pink noise was used at 60 dBnHL for ipsilateral masking of click stimuli.

Result and Discussion

In this section, the results obtained from the present study are discussed. The data obtained was subjected to statistical analysis using the SPSS (version 17.0) software. The results were analyzed to see how the latency shift of wave V responses for click alone and wave V for click + 0.5 kHz high pass masking noise (HPM) in both the groups. Further, analysis were done to measure the changes in latency of wave V for click alone and wave V for different frequencies HPM condition in both the groups. The above measurements were analyzed using descriptive statistics, Independent sample t-test and Wilcoxon signed rank test. Descriptive statistics was done to measure the significant difference between the values obtained from each group. The Wilcoxon sign rank test was administered to check whether there is a significant difference in CHAMP recording between individuals with normal hearing (non-Meniere's disease) and with Meniere's disease.

CHAMP in Individuals with Normal Hearing and with Meniere's disease

In control group, CHAMP was administered on total number of 33 ears (16 right and 17 left ears). Absolute latency of wave V responses was measured in six different high pass masking noise conditions i.e., click alone, click + 8 kHz HPM, click + 4 kHz HPM, click + 2 kHz HPM, click + 1 kHz HPM and 0.5 kHz HPM. All ears had wave V responses in click alone, click + 8 kHz, click + 4 kHz and click + 2 kHz HPM condition. However, 29 ears out of 33 ears (87.87 %) had wave V responses in click + 1 kHz HPM condition and only 24 ears out of 33 ears (72.72 %) had wave V response in click + 0.5 kHz HPM condition. The absence of wave V response in individuals with normal hearing could be because of undermasking condition. As literature suggests, even individuals with normal hearing required higher level of noise than the average which would be slightly under masked (Don, et al., 2005). The mean and the standard deviation of absolute latency of wave V response obtained for all conditions in individuals with normal hearing and with Meniere's disease are given in Table-1.

Table 1: *Mean and standard deviation (SD) of absolute latency of wave V responses in both groups*

	Individuals with Normal hearing			Individuals with Meniere's disease		
	No. of ears	Mean (msec)	SD	No. of ears	Mean (msec)	SD
Click alone	33	5.66	0.24	30	5.83	0.41
Click+8 kHz	33	6.01	0.30	30	5.99	0.43
Click+4 kHz	33	6.44	0.36	30	6.24	0.46
Click+2 kHz	33	6.74	0.54	30	6.44	0.59
Click+1 kHz	29	7.36	1.11	30	6.49	0.78
Click+0.5 kHz	24	7.44	1.34	26	6.50	0.94

In experimental group, 30 ears (16 left ear and 14 right ears) were tested for CHAMP in which absolute latency of wave V responses was measured in six different high pass masking noise conditions i.e., click alone, click + 8 kHz HPM, click + 4 kHz HPM, click + 2 kHz HPM, click + 1 kHz HPM and 0.5 kHz

HPM. All ears had wave V responses in click alone, click + 8 kHz HPM, click + 4 kHz HPM and click + 2 kHz HPM, click + 1 kHz HPM condition but wave V responses for click + 0.5 kHz HPM condition was found only in 26 ears out of 30 ears in this group. That indicates 86.66% Meniere's ears (72.72 % in contrast with normal ears) had wave V responses in click + 0.5 kHz HPM condition. The absence of wave V responses at 500 Hz HPM is sometimes difficult to obtain while recording CHAMP. It could be because of noise contamination or presence of post-auricular muscles artefact at click with ipsilateral 500 Hz HPM noise. Furthermore, sometimes in Meniere's disease individuals, the amplitude is so low at lower frequencies in high pass masking noise condition it is difficult to interpret wave V response. Also, as literature suggests there may be multiple points or peaks in an undermasked condition, probably due to noise contamination (Don et al. 2007). Hence, the present study too could not able to trace wave V at lower frequencies high pass masking noise due to above mentioned reason (Figure 1).

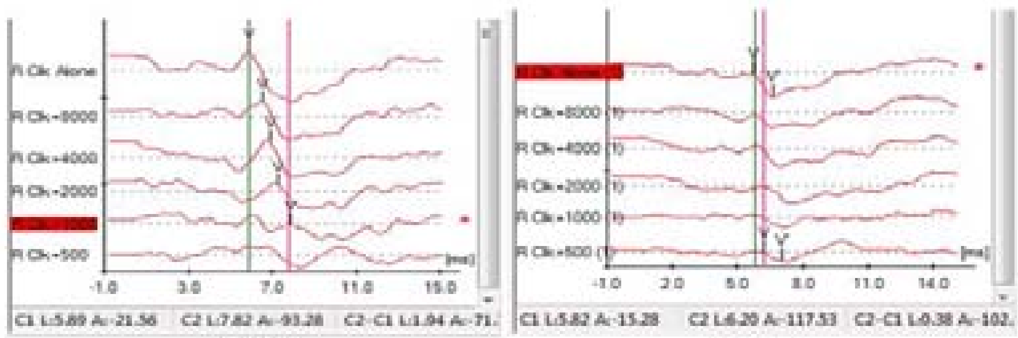

Figure A Figure B

Figure 1: *A sample waveform representing CHAMP in individuals with normal hearing (Figure-A) and Individuals with Meniere's disease (Figure-B)*

Table-1 clearly shows that as the cut-off frequency of the masking noise decreases, the latency of wave V increases since the whole basilar membrane is masked from basal to apical end. Further, this change in the peak could be expected because of the factors related to the travelling wave delay, the peak latency of the response increases as the area of the unmasked cochlea is successively restricted to lower frequencies (Don et al., 2005). The mean latency in control group for click alone condition was 5.66 msec whereas same increased up to 7.44 msec for the click + 0.5 kHz HPM condition.

Study by Singh (2010) showed mean latency of wave V responses for click alone as 5.70 msec and for click + 0.5 kHz HPM condition as 8.70 msec. The present study also showed similar findings for click alone and click + 0.5 kHz HPM condition. Furthermore, it is evident from Table-1 that the standard deviation (SD) is increasing as high pass masking noise is reducing which shows variability is more at low frequency high pass masking noise conditions.

In control group, the latency shift of wave V response from click alone condition to different high pass masking noise condition was determined by subtracting the latency of wave V response of click alone condition. The minimum mean latency shift was observed in click + 8 kHz HPM condition (0.35 msec), and the maximum mean latency shift (1.78 msec) for click + 0.5 kHz HPM condition. Previous studies (Don, et al., 2005; Singh, 2010) also illustrate the similar findings. The mean and the standard deviation of wave V latency shift for click alone and in different high pass masking noise conditions in individuals with normal hearing are summarized in table 2.

In experimental group, the latency shift in wave V response was observed for different high pass masking noise conditions, but it was observed that the latency shift was lesser than individuals with normal hearing group. The minimum mean latency shift was seen for click + 8 kHz HPM condition, 0.15 msec (0.35 msec in control group), and the maximum mean latency shift, 0.74 msec (1.78 msec in control group) was seen for click + 0.5 kHz HPM condition.

The present finding is in consonance with previous finding in literature (Don et al., 2005; De Valck et al., 2007; Ordonez-Ordonez et al., 2009; Kingma & Wit, 2010; Singh, 2010) which concludes that the latency shift of wave V is lesser in individuals with Meniere's disease as compared to individuals with normal hearing (Table 2).

The comparison of latency shift of wave V responses for different high pass masking noise conditions (click + 8 kHz, click + 4 kHz, click + 2 kHz, click + 1 kHz & click + 0.5 kHz) with wave V responses for click alone condition was done across the two groups using Wilcoxon signed ranks test. The findings of the comparisons are given in the Table 3.

Table 2: *Mean and standard deviation (SD) of wave V latency shift for click alone and different HPM noise condition in both groups*

	Individuals with Normal hearing			Individuals with Meniere's disease		
	No. of ears	Mean (msec)	SD	No. of ears	Mean (msec)	SD
Click+8 kHz - Click alone	33	0.34	0.21	30	0.15	0.32
Click+4 kHz - Click alone	33	0.78	0.32	30	0.41	0.40
Click+2 kHz - Click alone	33	1.08	0.51	30	0.62	0.53
Click+1 kHz - Click alone	29	1.72	1.06	30	0.66	0.77
Click+0.5 kHz - Click alone	24	1.78	1.28	26	0.73	0.94

The comparison in latency shift of wave V response for different HPM noise conditions with wave V response for click alone condition between both groups

Table 3*: Comparison of latency shift of wave V responses obtained from the difference of click alone and different HPM noise condition between both groups*

Different conditions	p-value
(click + 8kHz HPM) – click alone	0.005**
(click + 4kHz HPM) – click alone	0.000***
(click + 2kHz HPM) – click alone	0.004**
(click + 1 kHz HPM) – click alone	0.002**
(click + 0.5 kHz HPM) – click alone	0.002**

*p < 0.05; **p < 0.01; ***p < 0.001

From table-3 it can concluded that two groups i.e., control and experimental, are significantly different with respect to wave V latency shift in different noise conditions. This difference is expected as the physiology of inner ear differs in individual with normal hearing and with Meniere's disease. The basic principle is that the endolymphatic hydrops in Meniere's disease causes changes in the physical properties of the basilar membrane. These changes leads to significant undermasking of the high frequency regions by the noise, resulting in a large undermasked component in the 500 Hz high pass response. This undermasked component is valuable in the detection of endolymphatic hydrops.

Several researchers recommended the difference in latency shift from no masking noise condition (click alone) to maximum masking noise condition (click + 0.5 kHz) as the diagnosis criteria for Meniere's disease (Don et al., 1998; Don et al., 2005; De Valck et al., 2007; Ordonez-Ordonez et al., 2009; Singh, 2010). Similar comparison is done in the present study also to measure if the significant difference present between the two groups. Results of the present study revealed that there is a significant difference (Table 3) in the latency shift of wave V for click alone and click +0.5 kHz HPM conditions between the two groups.

This significant difference in the latency between two groups could be explained in terms of stiffness of the basilar membrane. The Endolymphatic hydrops might be confined at the apical part of the basilar membrane (Tonndorf, 1957) whereas in normal ears such stiffness is not seen. Therefore, the cochlea can easily be masked by 0.5 kHz high pass noise, hence there is more shift in latency of wave V in normal ears as compare to Meniere's ear.

Don et al. (2005) reported that Meniere's disease is confirmed if the wave V latency shifts in click + 0.5 kHz HPM from click alone condition is less than 0.3 msec but if it is more than 0.3 msec, Meniere's disease will considered to be absent. In the present study only seven Meniere's diseased ears out of thirty ears showed wave V latency shift less than 0.3 msec. which accounts only 23.3 % ears with Meniere's disease as per Don et al (2005) criteria. On the other hand, Kingma and Wit (2010) reported that latency shift with less than 0.3 ms diagnostic criterion, the sensitivity of the CHAMP reduces. Therefore they suggested using 2 msec as cut-off criterion the sensitivity of the CHAMP can be increases.

Similarly, in the present study if the cut-off latency value to diagnose active Meniere's disease is considered to be 1 msec then 62.5 % normal hearing ears can be separated from Meniere's disease ears and 88.45 % Meniere's disease ears will have abnormal short latency shift, which will confirm the diagnosis of active Meniere's disease. Hence present study is in consonance of Kingma and Wit (2010) finding.

Conclusions

The purpose of the present study was to find the diagnostic value of CHAMP in detection of Meniere's disease. It was administered on individuals with normal hearing and with Meniere's disease. The analyses was done for both the groups for latency shift of wave V for click alone and wave V for different HPM noise.

It can be concluded that CHAMP are effective diagnostic tool and these should be used for the diagnosis of active Meniere's disease. However, modification in the cut-off value to be incorporated. In the present study, it is observed that if the cut-off latency value to diagnose MD is considered to be 1 msec rather than 0.3 msec, 62.5% normal hearing ears can be separated from MD ears. Similarly, 88.45% MD ears will have abnormal short latency shift which was confirmed the diagnosis of MD. Hence, it can be concluded that this test can be used to distinguish objectively individuals with Meniere's disease with modification in cut-off criteria.

References

American National Standard Institute (1991). *Maximum permissible ambient noise for audiometric test rooms.* ANSI S3.1-1991. New York.

Committee on Hearing and Equilibrium (1972). Meniere's disease: criteria for diagnosis and evaluation of therapy for reporting. *Transactions of the American Academy of Ophthalmology & Otolaryngology, 76,* 1462-1464.

De Valck, C. F. J., Claes, G. M. E., Wuyts, F. L., & Paul, H. (2007). Lack of diagnostic value of high-pass noise masking of auditory brainstem responses in Meniere disease. *Otology and Neurotology, 28,* 700-707.

Don, M., Kwong, B., & Jos, J. (1998). The effect of Sensory Hearing Loss on Cochlear Filter Times Estimated from Auditory Brainstem Response Latencies. *Journal of Acoustics Society of America, 104,* 2280- 2288.

Don, M., Kwong, B., & Tanaka, C. (2005). A Diagnostic Test for Meniere's disease and Cochlear Hydrops: Impaired High Pass Noise Masking of Auditory Brainstem Response. *Otology and Neurotology, 26,* 711-72.

Don, M., Kwong, B., & Tanaka, C. (2007). An Alternative Diagnostic Test for Active Meniere's disease and Cochlear Hydrops Using High-Pass Noise Masked Responses: The Complex Amplitude Ratio. *Audiology and Neurotology,* 12, 359–370.

Donaldson, G. S. & Ruth, R. A. (1996). Derived-band auditory brainstem response estimates of travelling wave velocity in humans: II. Subjects with noise-induced hearing loss and Meniere's disease. *Journal of Speech and Hearing Research, 39,*534-545.

Flottorp, G. (1980). Cochlear non linearity in Meniere's syndrome. *Hearing Research, 2,* 407-409.

Hallpike, C. S., & Cairns, H. (1938). Observations on the Pathology of Meniere's Syndrome. *Proceedings of the Royal Society of Medicine, 31,* 1317-1336.

Horner, K. (1991). Old theme and new reflections: Hearing impairment associated with endolymphatic hydrops. *Hearing Research, 52,* 147-156.

Kingma, C. M., & Wit, H. P. (2010). Cochlear Hydrops Analysis Masking Procedure results in patients with unilateral Meniere's disease. *Otology & Neurotology, 31,* 1004-1008.

Ordonez-Ordonez, L. E., Rojas-Roncancio E., Hernandez-Alarcon, V, Jaramillo-Safon, R., Prieto-Rivera, J., Guzman-Duran, J., Lora-Falquez, J., Escobar, M. & Angulo-Martinez, E. S. (2009). Diagnostic test validation: cochlear hydrops analysis masking procedure in Meniere's disease. *Otology and Neurotolology, 30,* 820-825.

Ries, D. T., Rickert, M., & Schlauch, R. S. (1999). The peaked audiometric configuration in Meniere's disease: Disease related? *Journal of Speech, Language, and Hearing Research, 42,* 829-842.

Roeser, R. J., Valente, M., & Hosford-Dunn, H. (2000). *Audiology Diagnosis.* New York, USA: Thieme Medical Publishers.

Sajjadi, H., & Paparella, M. M. (2008). Meniere's disease. *The Lancet, 372,* 406- 414.

Singh, N. (2010). *Findings of Cochlear Hydrops Analysis Masking Procedure in subjects with suspected and confirm Meniere's disease.* Unpublished Master Dissertation submitted to the University of Mysore, India.

Thornton, A. R. D. & Farrell, G. (1991). Apparent travelling wave velocity changes in cases of endolymphatic hydrops. *Scandavian Audiology, 20,* 13-18.

Tonnodorf, J. (1957). The mechanism of hearing loss in early cases of Endolymphatic hydrops. *Annals of Otology Rhinology and Laryngology, 66,* 766-784.

DISABILITY ACCESS AUDIT OF PUBLIC SERVICE FACILITIES

[1]Venkatesan S., [2]Jayakaran G. T., [3]Purusotham P. & [4]Mahamed Rafi

Abstract

The present investigation adopts cross-sectional comparative case study design to undertake disability access audit on a sample of six representative public utility buildings located in the sprawling campus of All India Institute of Speech and Hearing, Ministry of Health and Family Welfare, Government of India, located in Mysore, Karnataka. After field trials, group discussions, on-site observations, interviews with unaffected and affected users, a final version of the 117-item 'Disability Access Audit Checklist' (DAAC) distributed across 15 domains was developed exclusively for data collection in this study. It was used by three independent and exclusively trained raters in the audit team. Results paint a rather grim picture on available accessibility for persons with disabilities at the studied institute. At the basic or beginning baseline level, it is seen that there is limited structural access score measuring no more than 29.2 % for all the target buildings included in this study. Even wherein few facilities like ramps, railings, furniture, lifts, corridors, lighting or flooring surfaces are available, their accessibility score drops markedly by almost a third to 9.1 % when adequacy criteria is adopted to demarcate 'genuine accessibility'. In conclusion, the study admits that the present endeavor is merely a beginning baseline benchmark for the oncoming alterations that need to be carried out in the relentless pursuit of universal design to provide greater accessibility for persons with disabilities as per the provisions mandated by the United Nations Convention on Rights for Persons with Disabilities (UNCRPD).

Key words*: Access Audit – Access Appraisal – Universal Design – Visitability - Disabilities*

The numbers and magnitude of disability in any given constituency continues to be a matter for dispute owing to disparities in definition or their identification. There are people with disabilities affected since birth. Others acquire them later in life. Ageing increases the risk of disability. Some are temporarily disabled, many others are permanently disabled. There are also visible and invisible disabilities. Some are marginally affected, others are severely disabled (Mahal, Debroy and Bhandari, 2010; Venkatesan, 2004; Fujiura and Rutkowski-Kmitta, 2001). Historically persons with disabilities were viewed as a misfortune of their own making. It was thought that the sins, follies or crimes committed in their previous birth were punished by divine forces as disability in the present birth. This 'magico-religious perspective' (Braddock and Parish, 2001) was later replaced by another 'medical model' to explain human disabilities as the consequence of insults in present life rather than retaliatory machinations of errors committed in ones past life. Thus, it was explained, how one becomes disabled owing to a faulty chromosome or an attack of brain fever. In recent times, both, these view points are refuted (Miller, Vandome and Mc Brewster, 2010; Albrecht, Seelman and Bury, 2001; Brisenden, 1998).

In a new revolutionary perspective following human rights movements, there has emerged the 'social model'. Rather than viewing human disability as the making or misfortune of the affected individual (Oliver and Sapey, 2006; Stroman, 2003; Fleischer and Frieda, 2001; 1998; Shapiro, 1993), it is seen as the intended or unwitting consequence of several barriers imposed by the larger system on the affected persons (Silvers, 2010; Fougeyrollas and Beauregard, 2001). The argument is that society is created and operated in a way without taking into account people who do not meet its perceived norm. Society excludes such people and thereby disables them (Ormerod, 2005). If one follows this model, use of the term 'people with disabilities' makes no sense. It views 'barriers' and not the individual per se as the source of the disability. For example, if a dwarf (vertically challenged) cannot operate a switch board at a height, the handicap is more from location of the board than in the individual. The barriers need not be physical alone. It could be attitudinal, systematic and institutionalized. The understanding that barriers are socially created and operated implies that they must be identified and tackled at their source rather than leave them as incidental or insignificant. Such barriers may be present in diverse areas including education, employment, urban design, transport, tourism and travel, leisure and recreation, housing, etc (Burnett and Bender-Baker, 2001).

[1]Professor in Clinical Psychology, All India Institute of Speech and Hearing (AIISH), Mysore-570 006, Email: psyconindia@gmail.com/ psyconindia@aiishmysore.in, [2]Occupational Therapist, AIISH, Mysore-570 006, Email: jayakarangt@rediffmail.com, [3]Research Assistant, AIISH, Mysore-06 & [4]Project Assistant, AIISH, Mysore-06

egalitarian equality,empowerment, and provision of opportunities to live life to the fullest extent. This approach insists on changes required in society in terms of attitude, supports, information, physical structures of buildings and community at large. This perspective has impacted many international conventions, laws, agreements or charters like Biwako Millennium Framework (BMF)(2003-2012), United Nations Convention on Rights of Persons with Disabilities (UNCRPD), Declaration on Rights of Disabled Persons (2006-07), Salamanca Statement and Framework for Action on Special Needs Education (1994), Standard Rules on Equalization of Opportunities for Persons with Disabilities (1993), Disability Discrimination Act or its newer form as Equality Act (2010) in United Kingdom, Americans with Disabilities Act (2009), Disability Discrimination Act in Australia, and Indian counterpart in Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995; or its ongoing revision as the new rights based Persons with Disabilities Act (2011) (Bagenstos, 2009; Pandey, Chirimar and D'Souza, 2005; Perry, 2004; Brading and Curtis, 2000). Some key terms operationalized by these revised views on persons with disabilities are: 'Universal Design' (Preiser and Ostroff, 2001; Aslaksen et al. 1997), 'Inclusive Design' (Gulatee, 2006; Maisel, 2006; Greed, 2003), 'Access Audit', 'Access Appraisal' (Sawyer and Bright, 2007), 'Visitability' (Cummings et al, 2008; Di Mento et al. 2006), 'Barrier Free Design' (Graafmans and Ikonen-Graafmans, 2003; Kose, 1998) and 'Tourism Access' (Deyer, 2005; Drill, 2005; Shelton and Tucker, 2005).

Need and Focus of Present Study

Among the 50 notified Articles in final text of UNCRPD, for which India is a signatory, 'accessibility' is earmarked as priority area. To ensure its timely implementation in all institutes/departments under its jurisdiction, an official notification (Z.28015/33/2009-MH; dated 10th June, 2010) was issued from Director General of Health Services (Medical Hospital Section-II) to audit and ameliorate disability access at all public service facilities.

Accessibility refers to the strength and degree to which persons with disability are provided for and enabled to live independently and participate in all aspects of life. Appropriate measures are mandated for and by necessary competent authorities to ensure their access, on an equal basis with others, to the physical environment, transportation, information, and communication, including such technologies and systems, other facilities and services open or provided to the public in urban and rural areas. These measures include identification and elimination of obstacles and barriers to accessibility. It applies inter alia to buildings, roads, transportation and other indoor and outdoor facilities, including schools, housing, medical facilities and workplaces; as well as information, communications and other electronic and emergency services. It also applies to

(a) developing, promulgating and monitoring implementation of minimum standards and guidelines for accessibility of facilities and services open or provided to the public;

(b) ensuring that private entities that offer facilities and services are open or provided to the public take into account all aspects of accessibility for persons with disabilities;

(c) providing training for stakeholders on accessibility issues facing persons with disabilities;

(d) providing in buildings and other facilities open to public signage in Braille and in easy-to-read and understand forms;

(e) providing forms of live assistance and intermediaries, including guides, readers and professional sign language interpreters to facilitate access to buildings and other facilities open to public;

(f) promoting other appropriate forms of assistance and support to persons with disabilities to ensure their access to information;

(g) promoting access for persons with disabilities to new information and communications technologies and systems, including the Internet;

(h) promote the design, development, production and distribution of accessible information and communications technologies and systems at an early stage, so that these technologies and systems become accessible at minimum cost.

Access audits fall across levels and types based on depth and scope of their applications. A basic structural level covers merely identification ('presence' or 'absence') of the various anatomical components in the facility under audit, such as, external approaches, entrance and reception, horizontal and vertical circulation, internal spaces and rooms, aids to communication, sanitary facilities, means of escape and evacuation, signage and information, care and management (Holmes-Siedle, 1996). The next level then gets into details on quality, strength, or allied dimensions of the targeted facility features. For example, at base level, one is interested in examining merely the presence or absence of ramps at the entrance of a building.

In next level, if the ramp is present, the audit proceeds to ascertain its quality, slope or gradient, flooring, landing area, edges or corners. Usually, such quantitative audits are measured against standards set up for each facility, such as, door width, position of various panels and manifestations, ramp gradients, corridor widths, height of facilities (toilets, basins or counters), circulation space, light or noise levels, door closing resistance, and water temperature. At still higher levels, access audit could focus on issues beyond structures into functional aspects. For example, a ramp might be cluttered with obstructive flower pots which prevent easy traffic flow of individuals. In short, 'structural' access audits assess presence of the facilities for disabled, 'functional' access audits move a step ahead to assess how well the facilities will work for them. This difference relates also to the way in which such access audits are carried out. The former uses tick-box approach to identify the presence/absence of a facility-which is the scope of this study. The latter involves a far more in-depth study into how the buildings actually work for the disabled people. It combines present picture of the building with recommendations on what should be done to improve it. Disability access audits are also differentiated as: 'open' and 'closed' depending on whether open grounds, play areas, parks, sports arenas, swimming pools or community facilities are involved or whether it covers enclosed spaces, indoor facilities, restaurants, etc.

A literature search on disability access audits came up as relatively unexplored arena of research work in South Asia (Gulatee, 2007; Grant, Highman and Tower, 2005; Holmes-Siedle, 1996). Despite legal enactments and right to access for persons with disabilities, their implementation is just beginning in our country. The lone report on disability access by 'National Center for Promotion of Employment for Disabled People' (NCPEDP) targeted five affiliated colleges under Delhi University covering structural points like toilets, library, classrooms, canteen, auditorium, etc. They used 5-point rating scale to evaluate disability friendliness. The scores were added and averaged for ranking the colleges. Results indicated highest score of 26/40 for one college and least score of 11/40 for another. The study also reported that the heads of these institutions were unaware of the special grants available for making educational institutions more accessible for students with disabilities (NCPEDP, 2008). In another unpublished report, a voluntary organization covered nine areas of access under the jurisdiction of Delhi University: parking, building entrances, general circulation area or corridors, signages, staircases, ramps, toilets, drinking water facility and emergency evacuation (Samarthyam, 2008).

Objectives

It was the aim of this study (a) to develop a preliminary tool to objectively measure the types or extent of structural accessibility; (b) to undertake an access audit of target public utility services with the developed tool for persons with disability; and, (c) to expand the scope of the access audit for examining areas like physical, quantitative, architectural and structural barriers in the adopted sample case studies of public utility services for persons with disability.

Method

The present investigation adopts cross-sectional comparative multi-case-study design to carry out disability access audit on representative sample of public utility buildings in the sprawling campus of All India Institute of Speech and Hearing (AIISH), Ministry of Health and Family Welfare, Government of India, located in Mysore, Karnataka.

Operational Terms

The term 'access audit' as used in this study refers to the exercise of objectively rating existing building or facility against a given criteria for usability and amenability for persons with disabilities. It covers not only issues related to movement in and around the building; but also, their use by people with disability for whom it is provided (NDA, 2002). 'Access audit' is distinguished from 'audit appraisal'. Access audits are undertaken for existing buildings or environments to examine their current situation and to make recommendations for improvements. 'Access appraisals' are carried out as part of the design process of new buildings or environments to make comments at key stages in development of the design which is not the focus of this study (Sawyer and Bright, 2007).
Another term 'universal design' reflects an 'ambition to create products and environments usable by all people without the need for adaptation or specialized design' (Goldsmith, 2000; Mace et al. 1999). They must be usable regardless of user with abilities or disabilities. Universal design is not quite the same as accessibility for people with disabilities-although the two terms are inter related. Some positive effects, at least in the western world, owing to access mandates in public places are ramps and elevators, as well as stairs, wide corridors and doors, textured walking surfaces, signs with

Braille characters, lowered drinking fountains and sinks, grab bars on walls in bathrooms, and audible crossing signals at street intersections. Thus, proponents of 'universal design' argue that, to be truly universal, environments must be shaped to fit a much broader population including the disabled (Goldsmith, 1997). Although the distinction between 'disability access' and 'universal design' is subtle, it nevertheless leads to different ways of thinking about design, to new principles and outcomes. The seven key principles of universal design with relevance to 'disability access' are as follows:

- Equitable use by all people with diverse abilities without segregating or stigmatizing anyone;
- Flexibility to use in anticipation of range of preferences and skills by providing user adaptability;
- Simple and intuitive use by avoiding unnecessary complexity and making the design comprehensible no matter what are the user's experience, knowledge or language skills;
- Perceptible information means employing multiple modes of expression-graphic, verbal or tactile-to achieve maximum clarity, legibility and speed of comprehension;
- Tolerance for error by minimizing hazards and adverse consequences of accidental or unintended actions;
- Low physical effort by minimizing physiological effort or fatigability in routine use;
- Size and space for approach and use to enable comfortable access, manipulation, use and operation.

Most developed nations have enforced use of 'universal or inclusive design' in any physical development of their cities for purpose of eliminating 'barriers' and enabling 'free access' or 'visitability' to persons with disabilities (Rahim and Abdullah, 2008). There are several western case studies on formal standard access audit systems of different sites (Wu et al, 2004; O'Connor and Robinson, 1999; Sue, 1999), or events (Darcy and Harris, 2003) by agencies for official certification with training programs for town planners, architects, civil engineers, curators, museologists and home builders (Russell, 2003).

Sample

The chosen six building facilities for disability access audit in this study include at AIISH are: Department of Clinical Services (CS); Department of Speech Language Pathology (SLP); Library Information Center (LIC), Academic Block (AB), Administrative Building (ADMN), and Gymkhana Building (GYM) (Table 1). .

Table 1: Comparative Profile of Target Facilities Included in the Present Study.

Variable	CS	SLP	LIC	AB	ADMN	GYM
Date of Construction	25.06.2003	16.10.2004	14.07.2001	10.08.2005	10.10.2005	
Plinth Area (Square Feet)	66000	33000	26000	23000	14000	14000
Parking Lots	1	-	1	-	-	1
Entrances/Exits	2	2	1	1	1	2
Ramps	2	1	1	3	1	1
Layout Maps	1	-	-	-	-	-
Floors	2	3	3	1	2	1
Rooms	179	59	29	27	31	10
Staircases	2	1	1	1	1	1
Lifts	1	1	1	1	1	-
Existing Toilets (HE/SHE)	10	6	2	4	7	5
Modified Toilets	-	-	-	-	-	-
Drinking Water Fountains	7	4	-	2	2	1
Balconies		-	-	-	-	-
Usage Density: Peak	200	150	150	350	75	50
Usage Density: Non- Peak	50	50	25	35	25	15

Clinical Services (CS); Department of Speech Language Pathology (SLP); Library Information Center (LIC), Academic Block (AB), Administrative Building (ADMN), Gymkhana Building (GYM)

The 'Department of Clinical Services' (CS) is nerve center for rendering diagnostic and therapeutic interventions to help-seeking clients by a team of rehabilitation professionals including audiologists, clinical psychologists, medical practitioners (ENT, neurology and pediatrics), occupational therapists, physiotherapists, speech language pathologists and special educators. It houses special clinical units to dispense individual/group counseling, conduct workshops/seminars, or for executing specialized assessment procedures. The average user density ratio per hour during peak and non-peak timings is estimated 200 and 50 for this facility, The 'Department of Speech Language Pathology' (SLP) is in a multi-storey building with equipment like diagnostic and therapeutic language lab hardware/software. The structure was holding a model 'preschool' (affiliated to another Department of Special Education) at the time of this study. The preparatory school for young children with special needs is a day-care unit combining parent preparation programs in batches during forenoon and afternoon sessions daily. The average user density ratio per hour worked out during peak and non-peak timings at 150 persons and 50 persons respectively.

The 'Library Information Center' (LIC) covers an area of 24000 square feet with ground area housing 'Book Section, Back Volumes of Journals, and Browsing Center', a section for display of new books, current journals and reference books, computer browsing center and spacious reading halls. The building and furniture are purported to be specially designed to meet functional and aesthetic requirements. It is surrounded by green lush lawn, rose garden and ornamental plants. The library is equipped with conventional resources and technology based information services. The average user density ratio per hour during peak and non-peak timings is pegged at 150 and 25 respectively. The 'Academic Block (AB) covers amenities like class rooms, seminar halls, video conferencing system connected across ten centers throughout the country. The average user density ratio per hour during peak and non-peak timings is estimated at 350 and 35 persons respectively. The 'Administrative Building' (ADMN) accommodates ministerial staff. The average user density ratio during peak and non-peak timings is pegged at 75 per hour and 25 per hour respectively. The 'Gymkhana Building' (GYM) is an association of staff and students of the institute. It is a platform for recreational, social and cultural activities. The sports complex has facilities for games, modern gymnasium and library. An open-air theatre is part of this sports complex. There is an auditorium with a seating capacity of 400 with modern audio visual systems. The average user density ratio per hour during peak and non-peak timings is pegged at 50 and 15 persons respectively.

Procedure

The actual access audit process was executed through well planned sequential and inter-related steps. Admittedly, it involved the preparation and participation of many people. Broadly, the audit process was conceptualized and completed in three distinct but inter-related phases between January-March, 2011: (a) Pre-audit Preparation; (b) Audit Process; and, (c) Post Audit Reporting and Follow up. In the first phase, after obtaining formal permission from competent authorities, indoctrination meetings were held between identified members in the audit team under coordination of the first author. The members in audit team included a clinical psychologist, occupational therapist, and two research assistants including one pursuing doctoral program and another post graduate in psychology. The official photographer was also part of the team. All the team members carried experience in the field of disability rehabilitation for periods ranging 5-25 years and one of the members is physically challenged and has limited mobility.

Standard disability access formats, some computerized, although available and merchandized in the west by accredited auditing firms, are generally need based inventories. They are often copyrighted, and not made available for outside use. Gulatee (2007) addresses accessible homes in a standard checklist along with possible solutions covering home style, entry, porches, hallways, kitchens, bathrooms, and closets. In another three part folder-cum-guide, a set of disability access audit checklists are made available (Feams, 1993). There are location specific access checklists for public buildings and environments (Flanagen et al, 2004), homes (Russell, 2003; Mace et al. 1999), library (Forrest, 2006), tourism and travel (Daniels, Drogin and Wiggins, 2005; Darcy, 2002), Universities or colleges (O'Connor and Robinson, 1999), hotels/ motels (Darcy, 2007), sports stadia or events like Paralympics (Darcy, 2003; Darcy and Harris, 2003). While checklists are often used initially, they must be viewed merely as aides-memoire rather than to be rigidly, routinely or ritually completed. They also serve as a common platform for comparison of various audit points within an estate or a given campus.

Based on literature search and through several in-house group discussions, brain storming, field observation and interviewing of clients with disabilities, an initial 'Disability Access Audit Checklist' was drawn with item pool of 96 items spread over 15 domains. After field trials, continued group discussions, on-site observations, interviews with non-affected and affected users, final version of the tool with 117 items distributed across 15 domains was developed. Care was taken to ensure that each item in the checklist was worded in observable and measurable terms. An access audit kit or tool box was also prepared comprising scoring sheets, measurement conversion tables, ruler, torch, string, compass, calculator, spring balance, digital camera, pressure gauge, light meter, sound meter, temperature recording devices, grad level to measure gradients of ramps, etc. (IPF, 2005). The scoring format involved marking each item as 'present' or 'absent'. If 'present', it was to be marked further as 'present adequately' or otherwise. Scores were nominated 'zero' for 'absent', 'one' for 'present' and 'two' for the feature 'present adequately' (Table 2).

Results

The overall results in terms of score as given by the three independent observers for all the six targeted access audit points included in the present study show an obtained mean score of 410 out of 1404 (Mean: 29.2 %). This implies a limited structural access of the buildings for persons with disabilities. On a further analysis of these obtained scores only for items 'present', it is seen that the access score drops to 128 out of 1404 marks (9.1 %). Therefore, truly speaking, 'genuine accessibility' of those structures in terms of they being 'present adequately' is found to be only 282 out of 1404 (20.1 %) (Table 2).

Among the six building structures audited in this study, the 'Library Information Center' (LIC) (Mean Score: 77 out of 234; 32.9 %), and another facility marked as 'Clinical Services' (Mean Score: 76 out of 234; 32.5 %) is 'more accessible' compared to 'Administrative Building' (Mean Score: 67 out of 234; 28.6 %), 'Academic Block' (Mean Score: 67 out of 234; 28.6 %), and 'Speech Language Pathology Building' (Mean Score: 66 out of 234; 28.2 %). The 'Gymkhana' (Mean Score: 57 out of 234; 24.4 %) is least accessible for persons with disabilities. These trends are similar even after discounting the 'merely present' factor.

Table 2: *Mean Raw Scores across various Audit Points.*

Code	Buildings	Access Audit Scores Max	Obtained	%	P	%	PA	%
A	Clinical Services	234	76	32.5	24	10.3	52	22.2
B	Speech Language Pathology	234	66	28.2	22	9.4	44	18.8
C	Library Information Center	234	77	32.9	25	10.7	52	22.2
D	Academic Block	234	67	28.6	23	9.8	44	18.8
E	Administrative Building	234	67	28.6	19	8.1	48	20.5
F	Gymkhana Building	234	57	24.4	15	6.4	42	17.9
	Overall	1404	410	29.2	128	9.1	282	20.1

(P: Present; PA: Present Adequately)

A second level analysis of disability access scores across the 15 audit locations in the six facilities (Table 3) shows that all buildings have adequate corridors with maximum width to enable wheel chair movement and without obstructions (Mean Score: 23 out of 24; 95.8 %), followed by 'seating systems' with arm rests, proper heights, or space for wheel chair bound (Mean Score Range: 31-44 out of 72; Percentage Range: 43.1-61.1 %), 'elevators/lifts' (Mean Score Range: 74-77 out of 168; Percentage Range: 44.0-45.8 %) with no obstacles in landing area, or non slippery lift floor surface. However, even in these moderate scoring items, for example, it is noted that lifts/elevators do not have 'audio system', 'space inside to facilitate wheel chair maneuverability', 'grab bars in the lift', 'lift door transparency', etc. Low scoring items on access for persons with disability cutting across all the audited buildings in this study include 'counters' (Mean Score: 9 out of 48; Percentage Range: 18.8 %) and 'canteen, cafeteria and food courts' (Mean Score: 5 out of 48; Percentage Range: 10.4 %). The 'counters' are reported as not having an 'adjustable height', 'lacking in across communicability', having no 'dropped reception desk area for wheelchair users', or a 'place to stand walking aids by the reception counter'. Similarly, the 'canteen, cafeteria and food courts' lacks 'adjustable height for communication across counters' and 'proper lighting system'.

It is also seen that at present all the buildings have received 'nil' score for 'designated parking lots', 'toilets, wash rooms, change rooms and bathrooms' and 'evacuation, emergency and egress facilities' meant exclusively for persons with disabilities. There are no exclusive earmarked parking lots labeled for disabled in the campus. Further, the mean distance between the places identified for parking are far away from the main buildings and posing challenges for persons with mobility impairment. There is no designated drop off points and the flooring remains uneven between parking lot and the main buildings. The 'public telephones, electrical fittings and fixtures' audited across buildings also receive 'nil' scores either for want of such a facility, or the available official ones having raised number boards or not having knee space or being amenable to wheel chair users, or individuals hard of hearing. The need and importance of 'evacuation, emergency and egress facilities' has not yet been recognized as evidenced by the nil score allotted across all buildings for the absence of 'safe refuge area', 'audible or visual fire alarm systems', 'safety protocol', 'evacuation chairs' at times of emergency. Even for the apparently available disability access amenities at 'entrance and reception area' (Mean Score Range: 123-138 out of 408; Percentage Range: 30.2-33.8 %) of the buildings under audit, it is important to note that there are several shortcomings. The ramps are unavailable on both sides of entrance, or they are measured to have steep gradients, lack railings on one or both sides, have sharp and unprotected edges, have obstructive decorative plants or there is no stand for wheelchair or crutches, or the steps in the stairways have nosing. The insides of the building have no signages. There are no exclusive toilets for the disabled (Table 3 & 4).

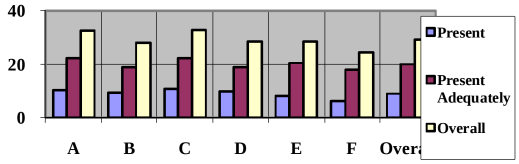

Table 3: Mean Raw Scores across Examiners for various Audit Points.

Location	Items	Max Marks	Rater	Audit Points A	B	C	D	E	F	Total Score	Access %
Entrance & Reception			ONE	24	22	24	22	22	24	138	33.8
Area	34	68	TWO	24	20	22	20	20	22	128	31.4
			THREE	20	19	23	20	20	21	123	30.2
			ONE	5	5	6	3	3	7	29	34.5
Insides/	7	14	TWO	5	5	6	3	3	7	29	34.5
Interna7			THREE	5	5	6	3	3	4	26	30.9
			ONE	14	17	14	14	18	-	77	45.8
Elevators/	14	28	TWO	13	16	14	14	17	-	74	44.0
Lifts			THREE	14	17	13	14	18	-	76	45.2
			ONE	-	-	-	-	-	-	-	-
Parking	6	12	TWO	-	-	-	-	-	-	-	-
Lots			THREE	-	-	2	-	-	-	2	2.7
Public Telephone/			ONE	-	-	-	-	-	-	-	-
Electrical Fittings	6	12	TWO	-	-	-	-	-	-	-	-
& Fixtures			THREE	-	-	-	-	-	-	-	-
			ONE	1	-	4	-	-	4	9	18.8
Counters	4	8	TWO	1	-	4	-	-	4	9	18.8
			THREE	1	-	4	-	-	4	9	18.8
Toilets/			ONE	-	-	-	-	-	-	-	-
Wash or Change Rooms/	11	22	TWO	-	-	-	-	-	-	-	-
Bathrooms			THREE	-	-	-	-	-	-	-	-
Drinking			ONE	1	1	1	3	1	1	8	22.2
Water	3	6	TWO	1	1	1	3	1	1	8	22.2
Facilities			THREE	2	1	-	3	1	-	7	19.4
Canteen,			ONE	5	-	-	-	-	-	5	10.4
Cafeterias	4	8	TWO	5	-	-	-	-	-	5	10.4
& Food Courts			THREE	5	-	-	-	-	-	5	10.4
			ONE	9	9	10	10	9	10	57	52.8
Stairways	9	18	TWO	9	9	10	10	9	10	57	52.8
			THREE	8	8	10	10	6	7	49	45.4
			ONE	3	4	4	4	4	4	23	95.8
Corridors	2	4	TWO	3	4	4	4	4	4	23	95.8
			THREE	4	3	4	4	4	4	23	95.8
			ONE	7	7	8	9	6	7	44	61.1
Seating Systems	6	12	TWO	7	7	8	9	6	7	44	61.1
			THREE	7	6	5	4	5	4	31	43.1
			ONE	2	2	4	1	2	-	11	30.6
Flooring/	3	6	TWO	2	2	4	1	2	-	11	30.6
Surfaces			THREE	2	2	4	2	2	-	12	33.3
Lighting,			ONE	2	2	2	2	2	2	12	33.3
Alarms &	3	6	TWO	2	2	2	2	2	2	12	33.3
Acoustics			THREE	2	2	2	2	2	2	12	33.3
Evacuation,			ONE	-	-	-	-	-	-	-	-
Emergency	5	10	TWO	-	-	-	-	-	-	-	-
& Egress Facility			THREE	-	-	-	-	-	-	-	-
			ONE	73	69	77	68	67	59	413	29.4
Total	117	234	TWO	72	66	75	66	64	57	400	28.5
			THREE	70	63	73	62	61	46	375	26.7

(A: Clinical Services: B: Speech Language Pathology; C: Library Information Center; D: Academic Block: E: Administrative Building; F: Gymkhana Building)

Table 4: *Summary Table of Items in Final Version of Disability Access Audit Checklist*

Item	*ENTRANCE*
1	*Color of entrance stands out*
2	*Alternative Entrance*
3	*Are there steps: If 'YES' how many*
4	*Are there steps in contrast color*
5	*Do the steps have railings*
6	*Railings on one side*
7	*Railings on both sides*
8	*Adjustable Height of Railings(Multiple)*
9	*Is there a ramp?*
10	*Ramp on one side*
11	*Ramp on both sides*
12	*Gradient/Slope of Ramp*
13	*Railings for Ramp on one side*
14	*Railings for Ramp on both side*
15	*Edge Protection for Ramp*
16	*Edge Protection for Ramp on one side*
17	*Edge Protection for Ramp on both side*
18	*Ramps within the building*
19	*Turnings in ramp*
20	*Is there intermediate landing area at the turnings*
21	*Surface of ramp*
22	*Is there landing area in top and bottom of the ramp*
23	*Width of Entrance*
24	*Type of Door: Circle Type: Automatic/Swing/Sliding;* *Door Closers/Bi-Divided/Unidirectional/Revolving/Bidirectional/Push-Pull Type*
25	*Door Handle: Circle Type: Lever/Knob/Latch/No Handle*
26	*Height of Door Handle*
27	*Any Decorations at Entrance: Permanent/Temporary*
28	*Wheel-chair Stand*
29	*Crutches Stand*
30	*Firm and even paths leading to Entrance from Parking Point*
31	*Tactile surfaces near curbs, doors and steps*
32	*Signs at entrance in Braille*
33	*Entrance door width*
34	*Layout map of the building*
	INSIDES
1	*Internal Doors width*
2	*Tactile Signage*
3	*Internal/External Signage is easy to read*
4	*Colors of walls contrasting doors and door frames*
5	*Control switch boards contrast doors & door frames*
6	*Height of Switch Boards*
7	*Transparent door system (vision panels)*
	ELEVATOR/LIFTS
1	*Entrance lead conveniently to lifts/elevators?*
2	*Audio system (Talking Lift) Installed*
3	*Space inside lift enough for wheel chair maneuverability?*
4	*Height of Call Buttons inside/outside Lift*
5	*Grab bars in the lift*
6	*Emergency Intercom in Lift*
7	*Lift Floor Non-Slippery*
8	*Opening/Closing Intervals Long Enough*
9	*Sufficiency of Entrance Landing Area*
10	*No obstacles in Landing Area*
11	*Availability of Audio Emergency Exit*
12	*Availability of Visual Emergency Exit*
13	*Lift area*
14	*Lift door transparency*
	PARKING LOTS
1	*Availability of Lot for Disabled*
2	*Distances between Lot and Building*
3	*Signboard Available indicating Parking for Disabled*
4	*Indicative/Directional Sign Boards in contrast colors*
5	*Flooring at Park Lot: Gravel/Smoothened/Anti-Skid/Sand/Others*
6	*Specific car drop off points*
	PUBLIC TELEPHONE/ELECTRICAL FITTINGS & FIXTURES
1	*Availability of Telephone*
2	*Height amenable for wheel chair Bound/Low height*

3	*Phone with Hearing Aid*
4	*Knee Space Available*
5	*Number board on phone raised*
6	*Text phone or type talk phone*
	COUNTERS
1	*Height of Counters for persons with disability*
2	*Communicability across*
3	*Dropped reception desk area for wheelchair users*
4	*Place to stand walking aids by reception & wash basins*
	TOILETS, WASH OR CHANGE ROOMS & BATHROOMS
1	*Separate toilets made available*
2	*Entrance accessible*
3	*Door width amenable for wheel chair*
4	*Floor space for Maneuverability*
5	*Faucets/Flush*
6	*Type of toilet: Indian/Western/Both*
7	*Height of Toilet Seat*
8	*Wash Basins*
9	*Doors lockable form in-released from out in emergency*
10	*Grab Bars; Slip Resistant/Load Bearing*
11	*Gender based toilet system*
	DRINKING WATER FACILITIES
1	*Water Faucet Height*
2	*Floor Area Dry*
3	*Mirrors at size and height*
	CANTEENS, CAFETERIAS & FOOD COURTS
1	*Table/Chair Provided*
2	*Leg Clearance Space Below Table*
3	*Is there proper lighting system*
4	*Counters height communicability across*
	STAIRWAYS
1	*Handrails Available*
2	*Height of Handrails*
3	*Grip available on the rail between for safe use?*
4	*Will it support at any point*
5	*Handrails continuous*
6	*No Nosing in stairs*
7	*Height of steps*
8	*Are there stairs in contrast color*
9	*Non slippery surface of stairs*
	CORRIDORS
1	*Maximum width to Enables wheel chair*
2	*No obstructions in the corridors*
	SEATING SYSTEMS
1	*Seating Heights*
2	*Supported with Arm Rests*
3	*No bucket type seating*
4	*Is seating system contrast in color*
5	*Reserved seats for PWD*
6	*Empty space for wheelchair bound*
	FLOORING SURFACES
1	*Slip resistant/Anti-Skip*
2	*No Gravel, Uneven & Carpeted*
3	*Tactile Ground Surface Indicators*
	LIGHTINGS, ALARMS & ACOUSTICS
1	*Visibility Friendly*
2	*Emergency Alarms*
3	*Sound Acoustics*
	EVACUATION, EMERGENCY & EGRESS FACILITY
1	*Safe refuge areas*
2	*Audible Fire Alarms*
3	*Visual Fire Alarms*
4	*Protocol in place for emergency*
5	*Evacuation chairs for emergency*

Inter-Observer Reliability: To determine the extent of agreement or concordance between the three raters using the 'Disability Access Audit Checklist' for the various points included in this study, inter-correlations between their ratings was estimated as index of reliability or consistency (Table 4). The results show consistently high inter-observer correlation coefficient ranging between 0.975-0.999. The Cronbach's alpha correlation coefficients of reliability of the sub-scales vary around 0.98 (range: 0.97-0.99) and internal consistency of the total scale is 0.98. This implies that the scales are not independent of one another.

Table 5: *Inter-Correlation Matrix across Examiners for various Audit Points.*

Buildings	Raters		
	A-B	B-C	C-A
Clinical Services	0.993	0.999	0.989
Speech Language Pathology	0.995	0.999	0.996
Library Information Center	0.989	0.998	0.985
Academic Block	0.978	0.998	0.975
Administrative Building	0.993	0.999	0.990
Gymkhana Building	0.987	0.999	0.981

In sum, the result of the present investigation paints a rather grim picture on accessibility for persons with disabilities in the studied institute. At the first level, it is seen that there is limited structural access score measuring 29.2 % for all target buildings included in this study. Even wherein few facilities like ramps, railings, furniture, lifts, corridors, lighting or flooring surfaces are available, their access score drops markedly to 9.1 % when adequacy criteria is adopted to demarcate 'genuine accessibility'. It is also seen that at present all the buildings have no 'designated parking lots', 'toilets, wash rooms, change rooms and bathrooms' and 'evacuation, emergency and egress facilities' exclusively for persons with disabilities. In conclusion, the present endeavor must be viewed as a beginning baseline or benchmark and harbinger for the oncoming alterations that is needed to be carried out in the institute and later throughout the country in the relentless pursuit of universal design to provide greater access for persons with disabilities.

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References

Albrecht, G.L., Seelman, K.D., & Bury, M. (Eds.). (2001). *Handbook of Disability Studies.* California: Sage Publications. Americans with Disabilities Act (2009). Washington, DC: US Department of Justice http://www.ada.gov/new.htm [accessed 26 November 2012]

Aslaksen, F., Bergh, S., Bringa, O. R., & Heggem, E. K. (1997). *Universal Design: Planning and Design for All.* Oslo: The Norwegian State Council on Disability.

Bagenstos, S. (2009). *Law and the Contradictions of the Disability Rights Movement.* London: Yale University Press.

Biwako Millennium Framework For Action Towards An Inclusive, Barrier Free And Rights Based Society For Persons With Disabilities In Asia And The Pacific. (2003-2012). Economic and Social Commission for Asia and Pacific, Geneva: United Nations Economic and Social Council, available at: http://www.unescap.org/esid/psis/disability/index.asp [accessed 26 November 2012].

Braddock, D.L., & Parish, S.L. (2001). 'An Institutional History of Disability'. Chapter 1 under Part 1: *The Shaping of Disability Studies as a Field.* In Albrecht, G. L., Seelman, K. D., & Bury, M. (Eds.). Handbook of Disability Studies. California: Sage Publications. Pp. 11-68.

Brading, J., & Curtis, J. (2000). *Disability Discrimination: A Practical Guide to the New Law.* London: Kogan Page Limited.

Bright, K., & Sawyer, A. (2004). *The Access Manual: Auditing and Managing Inclusive Built Environments.* Oxford: Blackwell.

Brisenden, S. (1998). Independent Living and the Medical Model of Disability. Chapter 2 under Part 1: From Activism to Academia. In Shakespeare, T. (Ed.). *The Disability Reader: Social Science Perspective*. London: Continuum. Pp. 20-27.

Burnett, J. J., & Bender-Baker, H. (2001). Assessing the Travel–Related Behaviors of the Mobility–Disabled Consumer. *Journal of Travel Research,* 40(1): 4-11.

Cummings, S., Oreskovich, J., Ravesloot, C., Seekins, T., & Traci, M.A. (2008). Assessing Environmental Factors that Affect Disability: Establishing a baseline of visitability in a rural state. *Rehabilitation Psychology,* 53(1): 80-84.

Daniels, M. J., Drogin, R.E.B., & Wiggins, B. P. (2005). Travel Tales: An Interpretive Analysis of Constraints and Negotiations to Pleasure Travel as Experienced by Persons with Physical Disabilities. *Tourism Management*, 26(6): 919-930.

Darcy, S. (2002). Marginalized participation: Physical disability, high support needs and tourism. *Journal of Hospitality and Tourism Management,* 9 (1): 61-72.

Darcy, S. (2003). The politics of disability and access: the Sydney 2000 Games experience. *Disability & Society*, 18 (6): 737-757.

Darcy, S. (2007). *A Methodology for Testing Accessible Accommodation Information Provision Formats*. Sydney: University of Technology. Pp. 1-18.

Darcy, S., & Harris R. (2003). Inclusive and Accessible Special Event Planning: An

Australian Perspective. *Event Management.* 8(1): 39-47

Declaration on the Rights of Disabled Persons: Proclaimed by General Assembly resolution 3447 (xxx) of 9.12.1975 (2006-07), available at:

http://www2.ohchr.org/english/law/res3447.htm [accessed 26 November 2012]

Deyer, J.W. (2005). Decoding accessible design terms. *Paraplegia News,* 59(1): 24-28.

Di Mento, J.F.C.; Geis, G., Kaminshi, S.E., & Mazumdar, S. (2006). The viability of voluntary visitability: A case study of Irvine's approach. *Journal of Disability Policy Studies,* 17(1): 49-56.

Drill, H. (2005). A closer look: A move toward accessible hotels. *Paraplegia News,* 59(1): 53-55.

Feams, D. (1993). *Access Audits: A Guide and Checklist for Appraising the Accessibility of Buildings for Disabled Users.* London: Center for Accessible Environments

Flanagen, S., Cook, G., Embleton, J., Bright, K., & Selbekk, L. (2004). *Buildings for all to Use: Improving the Accessibility of Public Buildings and Environments.* London, UK: CIRIA

Fleischer, D.Z, & Frieda, Z. (2001). *The Disability Rights Movement: From Charity to Confrontation. Philadelphia:* Temple University Press,

Fleischer, D.Z., & Frieda, Z. (1998). Disability Rights. *Social Policy* 28(1): 52-55.

Forrest, M.E.S. (2006). Towards an Accessible Academic Library: Using the IFLA checklist. *IFLA Journal*. 32(1): 13-18.

Fougeyrollas, P., & Beauregard, L. (2001). Disability: An Interactive Person-Environment Social Creation. Chapter 6 under Part 1: The Shaping of Disability Studies as a Field. In Albrecht, G. L., Seelman, K. D., & Bury, M. (Eds.). *Handbook of Disability Studies.* California: Sage Publications. Pp. 171-194.

Fujiura, G.T., & Rutkowski-Kmitta, V. (2001). 'Counting Disability'. Chapter 2 under Part 1: The Shaping of Disability Studies as a Field. In Albrecht, G. L., Seelman, K. D., & Bury, M. (Eds.). *Handbook of Disability Studies*. California: Sage Publications. Pp. 69-96.

Fuller, C. (2008). *Fire and Disability 2008: A Special Report.* Cambridge: Workplace Law Publishing

Goldsmith, S. (1997). *Designing for the Disabled: The New Paradigm.* Boston: Architectural Press.

Goldsmith, S. (2000). *Universal Design: A Manual of Practical Guidance for Architects*. Burlington: Architectural Press.

Graafmans, J.A.M., & Ikonen-Graafmans, T.S.K. (2003). The barrier-free suburb of Marjala in Finland: The city for all - the Marjala Model. *Technology and Disability,* 15(3): 201-204.

Grant, A., Highman, P., & Tower, B. (2005). *Access Audit Handbook: A Planning Tool for Appraising the Accessibility of Public Buildings.* London, UK: Riba Enterprises.

Greed, C. (2003). *Inclusive Urban Design: Public Toilets.* Oxford: Architectural Press.

Gulatee, R. (2006). Designing your accessible home: Working with a specialized architect. *Exceptional Parent,* 36(7): 26.

Gulatee, R. (2007). Creating Accessible Homes: A Checklist for Accessibility. *Exceptional Parent,* 37(11): 52-54.

Holmes,-Siedle, J. (1996). *Barrier Free Design: A Manual for Building Designers and Managers.* Oxford, UK: Butterworth-Heinemann. IPF. (2000). *CIPFA Property Consultants Disability Access Audit Tool Kit: Version 1.1, Users Manual.* Paris: Institute of Public Finance.

Kose, S. (1998). From barrier-free to universal design: An international perspective. *Assistive Technology,* 10(1): 44-50.

Mace, R.L., Pace, R.J., Trachtman, L.H., & Young, L.C. (1999). The universal design home: Are we ready for it? *Physical and Occupational Therapy in Geriatrics,* 16(3-4): 1-18.

Mahal. A., Debroy, B., & Bhandari, L. (Eds.). (2010). *India: Health Report-2010*. New Delhi: Business Standard Books. Pp. 42.

Maisel, J.L. (2006). Toward inclusive housing and neighborhood design: A look at visitability. *Community Development: Journal of the Community Development Society,* 37(3): 26-34.

Miller, F.P., Vandome, A.F., and Mc Brewster, J. (2010). *Medical Model of Disability*. Germany: VDM Publishing.

National Center for Promotion of Employment for Disabled People. (2008). http://www.dnis.org/Employment.pdf [accessed 26 November 2012]. NDA (2002). *Building for Everybody*. Dublin: The National Disability Authority.

O'Connor, U., & Robinson, A. (1999). Accession or Exclusion? University and the disabled student: A Case study of Policy and Practice. *Higher Education Quarterly*. 53(1): 88-103.

Oliver, M., & Sapey, B. (2006). *Social Work with Disabled People.* Palgrave: Macmillan.

Ormerod, M. (2005). Understanding access audits and appraisals: An inclusive design approach. *Journal of Building Appraisal*, 1(1): 140-152

Pandey, S., Chirimar, P., and D'Souza, D. (2005). *Disability And The Law: Human Rights Law Network, India*. New Delhi: Human Rights Law Network.

Perry, P. (2004). *Winning with the Disability Discrimination Act: A Guide for Business*. London: Business Information. Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act. (1995). Government of India: Ministry of Social Justice and Empowerment. http://socialjustice.nic.in/pwdact1995.php [accessed 26 November 2012]

Preiser, W. F. E., & Ostroff, E. (2001). *Universal Design Handbook.* New York: McGraw-Hill.

Rahim, A.A., & Abdullah, F. (2008). Access Audit on Universal Design: The Case of Kota Kinabalu Water Front. *The International Journal of Interdisciplinary Social Sciences,* 4(4): 49-58.

Russell, P. (2003). Access and Achievement or social exclusion?' Are the government's policies working for disabled children and their families. *Children and Society*. 17(3): 215-225.

Samarthyam: National Center for Accessible Environments (2008). *Access Audit Report under the Project Accessible University of Delhi.* New Delhi: Samarthyam Trust.

Sawyer, A. & Bright, K. (2007) 'Access Audits and Appraisals'. In '*The Access Manual: Auditing and Managing Inclusive Built Environments*', Second Edition. Oxford, UK: Blackwell.

Shapiro, J.P. (1993). *No Pity: People with Disabilities Forging a New Civil Rights Movement*. New York: Times Books.

Shelton, E. J., & Tucker, H. (2005). Tourism and disability: issues beyond access. *Tourism Review International*, 8(3): 211-219.

Silvers, A. (2010). An Essay on Modeling: Their Social Model of Disability. Chapter 2 under Part 2 on 'Concepts and Theories of Disability'. In Ralston, D.C., and Justin Ho. (Eds.). *Philosophical Reflections on Disability*. London: Springer. PP. 19-36.

Smith, M. (2006). *Using the Building Regulations: Part M Access*. Burlington: Butterworth-Heinemann.

Standard Rules on Equalization of Opportunities for Persons with Disabilities. (1993). http://www.un.org/documents/ga/res/48/a48r096.htm [accessed 26 November 2012]

Stroman, D. (2003). *The Disability Rights Movement: From Deinstitutionalization to Self-Determination. Maryland;* University Press of America.

Sue, W. (1999). *Access for Disabled People to School Buildings: Management and Design Guide*. London, UK: Publications Centre. The Disability Discrimination Act of United Kingdom. (2007). http://www.legislation.gov.uk/uksi/2007/2405/contents/made [accessed 26 November 2012]

United Nations General Assembly, Convention on the Rights of Persons with Disabilities: Resolution adopted by the General Assembly, 24 January, 2007, A/RES/61/106, available at: http://www.unhcr.org/refworld/docid/45f973632.html [accessed 26 November 2012]

Venkatesan, S. (2004). *Children with Developmental Disabilities: A Training Guide for Parents, Teachers and Caregivers.* New Delhi: Sage..

Waterman, I., & Bell, J.A. (2004). *Disabled Access Facilities: A Practical and Comprehensive guide to a service Provider's duties under Part III of the Disability Discrimination Act 1995.* London: Butterworths.

Wu, S., Lee, A., Koh, W.W.I., Aouad, G., & Fu, C. (2004). An IFC-based space analysis for building accessibility layout for all users, Construction Innovation: Information, *Process, Management,* 4(1): 129 – 141.

EFFECT OF FAST AND SLOW COMPRESSION ON VOICE ONSET TIME IN HEARING AID PROCESSED SPEECH

[1]Ajish K. Abraham

Abstract

Compression introduces distortion in hearing aid processed speech, when compared with linear amplification. Static parameters of compression namely compression ratio, compression threshold, attack time (AT), release time (RT) as well as the number of compression channels of a hearing aid may be the potential sources of compression induced distortion. The role of hearing aid compression parameters on speech perception and sound quality of hearing aids has been investigated in several studies. In some studies, it has been reported that, long ATs/ RTs leads to improvement in intelligibility of speech sounds. However, further research is required to find out the factors responsible for this. The present study therefore, investigated the influence of slow and fast compression time constants on transformation of voice onset time (VOT) in hearing aid processed speech. The objectives of the study were (1) to measure the Attack Time and Release Time of four behind the ear Digital Hearing Aids programmed in fast and slow AT/RT settings and (2) to investigate the effect of slow and fast AT/RT on VOT transformation. Six plosives in CV syllables categorized as: - unvoiced – velar /k/, dental /t/, and bilabial /p/, voiced – velar /g/, dental/d/ and bilabial /b/ produced by an adult (native Kannada) male speaker at a comfortable loudness level were recorded and used as stimulus for the study. AT and RT values of all four hearing aids in slow and fast compression setting were evaluated as per the test procedure specified by American National Standards Institute (ANSI) S3.22 standard. VOT values were measured for the input stimuli and the digitized hearing aid processed speech samples by using speech analysis software and the transformation in VOT was estimated. Results showed a reduction in VOT for voiced and unvoiced plosives at fast compression time constant setting. However, no changes in VOT was noticed at slow AT/RT setting, for unvoiced plosives, but significant difference was observed for voiced plosives.

Keywords: *Compression Speed, Attack Time, Release Time, Speech intelligibility, Temporal Distortion*

Speech includes a wide and dynamic range of intensity levels, ranging from low intensity consonants (for eg: /f/) to high intensity vowels (for eg: /i/). Intensity levels also vary from soft speech (low intensity) to loud speech (high intensity). To bring all these intensity levels within the dynamic range of hearing of a person with hearing impairment, most hearing aids offer some form of compression in which gain is automatically adjusted on the basis of the intensity of the input signals. Hearing aids with wide dynamic range compression (WDRC) feature adjust their gain automatically, based on the measured level of the input signal. This may introduce distortions to input signals, which would be much higher than which is introduced in hearing aids with linear amplification. Static parameters of compression namely compression ratio, compression threshold, attack time (AT), release time (RT) as well as number of compression channels in hearing aid are all potential sources of compression induced distortion. As reported by Souza, 2002, the speed at which a hearing aid alters its gain according to changes in input sound levels, is considered as a major parameter of a compression hearing aid. As defined by American National Standards Institute (ANSI), attack time is the time interval between the abrupt increase in the input sound level and the point when the output sound level from the hearing aid stabilizes to within + 2dB of the elevated steady state level. Similarly, release time is the time interval between abrupt reduction in the steady state input signal level after the hearing aid amplifier has reached the steady state output under elevated input conditions, and the point at which the output sound pressure level from the hearing instrument stabilizes within +2dB of the lower steady state level (Vonlanthen & Arndt, 2007).

The influence of hearing aid compression parameters on speech perception and sound quality of hearing aids has been investigated in several studies done by Gatehouse, Naylor & Elberling, (2006); Hansen, (2002); Moore, Stainsby, Alcantara, & Kuhnel, (2004); Neuman, Bakke, Mackersie, Hellman, & Levitt, (1998) (Quoted by Shi & Doherty, 2008). A literature review by Gatehouse et al., 2006), reveals that

[1]Reader in Electronics & Acoustics, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: ajish68@aiishmysore.in

some researchers (e.g., Moore et al., 2004) have found no effect of time constants, while others have found fast-acting compression to be superior to slow acting compression (e.g., Nabelek & Robinette, 1977), while yet others have found slow-acting compression to be superior to fast-acting compression (e.g., Hansen, 2002). Ole Hau & Andersen (2012) commented that this discrepancy is because, these studies were designed to investigate different outcomes. Some of the studies focused on the effect of time constant on speech intelligibility (e.g., Nabelek et.al., Nabelek & Robinette, 1977; Moore et al., 2004), while others (Neuman et al.; 1998; Hansen, 2002) focused on subjectively perceived sound quality. Gatehouse et. al. (2006) attributed this discrepancy to the differing signal processing strategies and compression algorithms incorporated in the hearing aids used for these studies.

Fast AT (≤ 10 ms) and fast RT (≤ 150 ms) helps the compression system to react to changes in sound pressure level between syllables, resulting in increased temporal distortion in comparison with slow AT/RT (Shi & Doherty, 2008). Stone and Moore (2007) reported that envelop distortion of running speech is more with fast compression when compared with slow compression (AT is ≥ 350 ms, RT ≥1080 ms). Shi et al., (2008) reported that with slow AT/RT, real ear aided response is better than fast AT/RT and linear amplification.

To stress the need for more research to find out which AT/RT settings are ideal for improved intelligibility for listeners, Shi et al., (2008) has analyzed the following studies. In an effort to find the combined effect of a fast AT/RT and high compression ratio (CR) on intelligibility of vowels (VCV syllables), Van Tasell and Trine (1996) conducted an experiment and found that the combination resulted in low intelligibility. Studies conducted by Moore & Glasberg, (1988); Moore, Glassberg, & Stone, (1991); Stone & Moore, (2004) have also shown that speech intelligibility increases with long ATs/RTs. But Gatehoue et al., (2006) and Jenstad & Souza, (2005) reported that there is no consistent increase in intelligibility of phonemes with long RTs. According to Jenstad et al., (2005) some plosives and affricates were reported to be better intelligible with a lesser RT (12 ms) in comparison with a longer RT (800 ms). Studies by Moore et al., (2004) and Stone et al., (1999) shows that there is no significant increase in speech intelligibility in case of slow AT/RT over fast or vice versa.

An investigation is required to find out the effect of different compression time constants on the temporal parameters of speech. Along with this, the factors responsible for the contradictory results need to be investigated. A recent study conducted by the author on hearing aid processed speech has revealed that the voice onset time gets transformed significantly while the speech signal passes through the signal processing stages in a digital hearing aid. VOT is defined as the time difference between the onset of burst and the onset of voicing in stop consonants (Kent & Read, 1995). VOT forms an important cue to signify voicing contrast in word-initial stop consonants. For unvoiced stops, the burst release takes place before the onset of glottal activity and for voiced stops it follows the onset of glottal activity. Shobha, Thomas and Subba Rao, (2009) studied the effect of VOT modification on speech perception in noise. They have reported that, for no noise presentations, VOT modification in voiced and voiceless stops reported a benefit up to plus 4% for few conditions. Nataraja, Savithri, Sreedevi and Sangeetha (2000) evaluated the improvement in speech intelligibility after transforming the temporal parameters in the speech of hearing impaired children. Results showed that VOT transformation was the one with maximum effect and its enhancement has led to significant increase in speech intelligibility. Hence VOT transformation in slow and fast AT/RT settings can be a potential factor influencing speech intelligibility, which could throw some light on the conflicting results reported in the previous studies. Hence the effect of slow and fast AT/RT on VOT modification needs to be investigated.

Gatehouse et al., (2006), reveals that, in all studies of compression, it is important to ensure that test conditions reflect a relevant diversity of signal characteristics. This is because of the fact that the characteristics of the test signals used may influence the results of evaluation of AT/RT. This is especially true as the object of present study is time constants, since varying these can fundamentally alter the nature of the nonlinearity. Hence there is a need to measure the AT & RT of all the hearing aids used in the study as per the protocol specified by American National Standard Institute (ANSI).

The present study therefore, investigated the influence of slow and fast compression time constants on transformation of VOT in hearing aid processed speech. The objectives of the study were (1) to measure the Attack Time and Release Time of four Digital Hearing Aids configured in fast and slow settings of compression speed and

(2) to investigate the effect of slow and fast AT/RT on VOT transformation.

Method

a) Experiment 1- Measurement of AT and RT

Stimuli: A 1,600 Hz pure tone signal at 55dB SPL was used as test signal. This signal was modulated by a square envelope pulse increasing the input level by 25dB. The pulse length was kept at least five times longer than the attack time being measured. Intervals between two consecutive pulses were kept at five times longer than the recovery time being measured (Vonlanthen et al., 2007).

Instrumentation: The setup used for measurement is shown in figure 1. Test signal, generated by a Matlab program in the computer as a wave file is downloaded to the front end of B & K pulse analyzer system. The hardware unit of the pulse analyzer system delivers the stimulus through B & K 2716C precision power amplifier and a leveled response loudspeaker to the hearing aid under test kept in the hearing aid test chamber (B & K 4232). Four behind the ear (BTE) digital hearing aids were used for testing. These hearing aids had the option to select two AT/RT settings:- slow and fast. All hearing aids were programmed with a flat gain curve for mild hearing loss. The output is acquired from all 4 hearing aids for each of the setting by B & K 4189 condenser microphone that is placed inside a 2cc coupler and are recorded by BZ 7226 recording setup and stored on the PC for analysis.

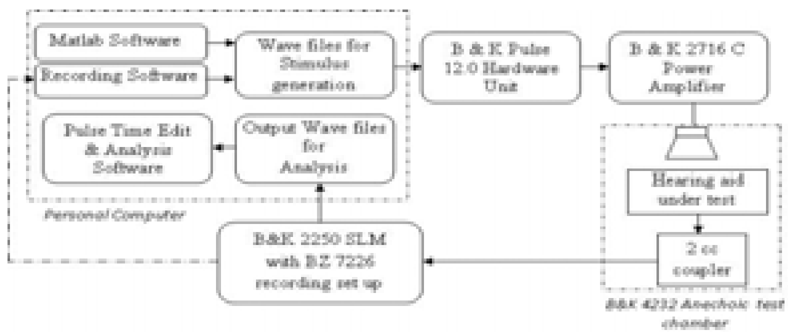

Figure 1*: Instrumentation for stimulus delivery and AT/RT/VOT Measurement*

Test environment: All the tests were carried out in an air conditioned sound treated room. The ambient noise levels were within permissible limits.

Measurement: AT/RT values were measured as specified by ANSI S3.22 standard from the digitized hearing aid output by using a speech analysis software (B & K Pulse Time Edit & Analysis). AT was measured as the duration between the abrupt increase in the input signal level and the point when the output sound pressure level from the hearing aid stabilizes to within ± 2 dB of the elevated steady state level, as illustrated in figure 2. RT was measured as the duration between the abrupt reduction in the steady state input signal level and the point when the output sound pressure level from the hearing aid stabilizes to within ± 2 dB of the lower steady state level. (Vonlanthen et al., 2007)

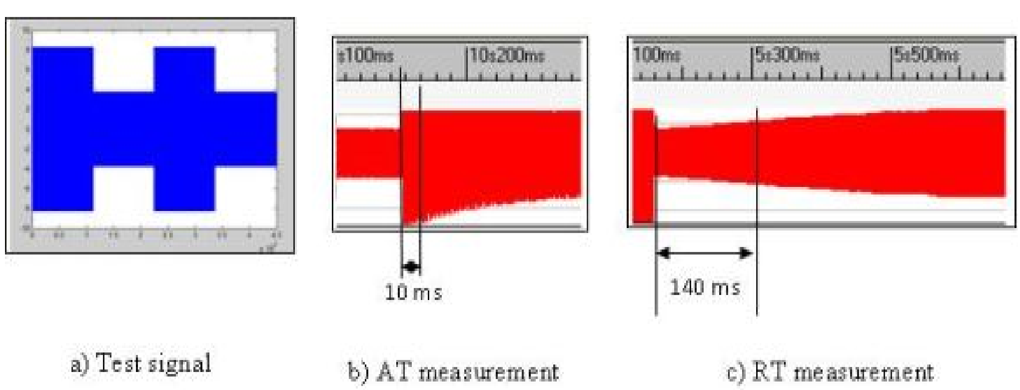

Figure 2: *Illustration of measurement of AT and RT*

Reliability measurements: In order to ensure the consistency and reliability in VOT measurements, intra-judge reliability was assessed. For this, 30% of the measured values were selected (on random basis) and reevaluated by the same investigator. Absolute percent errors were used to indicate the intra-judge reliability of measurement.

Results showed an absolute percent error of 3.92% between the measurements done by the primary investigator, which indicate that the primary investigator was consistent and reliable in AT/RT measurements.

b) Experiment 2 - VOT Measurement

Stimuli: Six CV syllables, including /ka/, /pa/, /ta/, /ga/, /da/ and /ba/ were used for the study. The stimuli comprised of six stop consonants in the initial position categorized as:- unvoiced – velar /k/, dental /t/, and bilabial /p/, voiced – velar /g/, dental /d/ and bilabial /b/

Recording: The utterance of each stimulus produced by an adult (native Kannada) male speaker at a comfortable loudness level was recorded. Speech samples were acquired by a condenser microphone (B & K 4189) that was kept at a distance of 6" from the mouth of the speaker at an angle of 30^0 azimuth. Speech samples were immediately digitized at a sampling frequency of 22 kHz and 16 bits sample by using a sound recording set up (BZ7226, Bruel & Kjaer, Denmark) facilitated in a precision Type I sound level meter (B & K 2250). Wave files were then transferred on to a PC for delivery and analysis.

Instrumentation: The setup used for measurement and analysis was the same as in experiment1 (figure 1). Recorded stimuli, stored on to the computer as a wave file is downloaded to the front end of B & K pulse analyzer system. These hearing aids had the option to select two AT/RT settings:- slow and fast. All hearing aids were programmed with a flat gain curve for mild hearing loss. The output for each of the stimuli were acquired from all 4 hearing aids, recorded by BZ 7226 recording setup and were stored on to the PC for analysis.

Acoustic Analyses: VOT was measured from the digitized hearing aid processed speech samples (Figure 3) for both slow and fast AT/RT setting, by using a speech analysis software (B & K Pulse Time Edit & Analysis). The difference in time between the release of a complete articulatory constriction and the onset of quasi-periodical vocal fold vibration was noted as VOT. VOT values were directly measured from the waveform with the help of two cursors, the first one indicating the release of the burst, and the second one at the first distinguishable period of onset of the vowel (Lisker & Abramson, 1964). VOT (in milliseconds) was noted as the time interval between the two cursors as illustrated in figure 3. Spectral analysis using Pulse Analyzer (B & K) was done to locate these points whenever the burst or vowel onset was difficult to be located from the waveform.

Statistical analysis: Statistical analysis was carried out using commercially available SPSS (Version 18) software. Wilcoxon signed ranks test was administered to find the effect of slow and fast AT/RT on transformation of VOT.

Results and Discussion

Measurement of AT/RT: The results indicated that the hearing aids used for the study were having their AT ≤ 10 ms and RT ≤ 150 ms (Shi et al., 2008) in fast setting. In slow setting all the hearing aids showed an AT ≥350 ms and RT ≥1080 ms (Stone et al., 2007). As suggested by Gatehouse et al., (2006), the measurement was done in such a way that the validity of the test results were ensured. Thus these results have consolidated that all the hearing aids used for the study were having their AT & RT in slow and fast category at the programmed settings and the test conditions. The results also rule out the possibility of change in AT/RT due to the type of signal processing strategy or compression algorithm. Table 1 shows the AT and RT of all the four hearing aids used for the study, in both slow and fast setting.

Table 1: *Measured AT / RT values of hearing aids used for study.*

Hearing aids	Slow AT (ms)	Slow RT (ms)	Fast AT (ms)	Fast RT (ms)
Hearing aid 1	380	1150	10	140
Hearing aid 2	500	1200	10	100
Hearing aid 3	480	1120	9	105
Hearing aid 4	420	1180	10	90

Transformation of VOT in slow and fast AT/RT settings: VOT reduced by 7.33 ms and by 6.58 ms in unvoiced and voiced plosives, respectively under fast AT/RT settings. The reduction was longer for unvoiced plosives compared to voiced plosives. Further VOT reduced to a greater effect for velar unvoiced plosives compared to other places of articulation. It was interesting to note that VOT reduction was least in velar voiced plosive. Hearing aid 3 was better than the other hearing aids. VOT reduced by 6.50 ms and 0.83 ms for unvoiced and voiced plosives respectively in slow AT/RT setting. Also, VOT reduced to a greater extent for velar unvoiced plosive compared to others. Further, VOT transformation was negligible for voiced plosives. Performance of Hearing aid 2 was better compared to other hearing aids. Table 2 shows the reduction in VOT in fast and slow AT/RT settings and table 3 shows the mean, media and SD of reduction in VOT.

Table 2*: Reduction in VOT (ms) for plosives in fast and slow AT/RT setting*

		Fast AT / RT setting			
Stimuli /Hearing aid		1	2	3	4
		Change in VOT (ms)			
Unvoiced	/ka/	15	15	12	15
	/ta/	3	3	2	5
	/pa/	5	5	3	5
Voiced	/ga/	5	5	5	4
	/da/	10	5	10	5
	/ba/	10	10	5	5
		Slow AT / RT setting			
Unvoiced	/ka/	10	8	12	15
	/ta/	3	3	3	5
	/pa/	5	5	4	5
Voiced	/ga/	0	2	0	2
	/da/	0	0	4	2
	/ba/	0	0	0	0

Table 3: *Mean, Median and SD of reduction in VOT (ms) for fast and slow AT/RT setting*

	Fast AT / RT setting		Slow AT / RT setting	
	Unvoiced	Voiced	Unvoiced	Voiced
Mean	7.33	6.58	6.50	0.83
Median	5.00	5.00	5.00	5.00
SD	5.26	2.53	3.91	1.33

The results revealed a high SD in both conditions. Wilcoxon Signed Ranks Test was administered to ascertain the effect of slow/ fast RT on transformation in VOT. Results revealed no significant difference between conditions (fast and slow) for unvoiced plosives {$|z|$=0.736, $p>0.05$} and significant difference between conditions for voiced plosives {$|z|$ = 3.089, $p<0.01$}.

Improvement in speech intelligibility was reported from previous studies conducted by Moore et al., (1988), Moore, Glassberg & Stone (1991), Stone & Moore (2007) when ATs/RTs were slow. Results of the present study support these findings as slow AT/RT settings did not bring any transformation in VOT of voiced plosives, and hence account for the improved speech intelligibility. Nataraja et al., (2000) reported that transformation of VOT would bring changes in speech intelligibility and hence a reduction in VOT would result in reduced intelligibility. Fast AT/RT setting showed reduction in VOT for both voiced and unvoiced plosives and this accounts for reduced intelligibility. This also explains the reported finding of Stone et al., (2007) that there is higher envelop distortion of running speech with fast compression than with slow compression

Results of the present study also show no significant difference between conditions for unvoiced plosives. Possible reason for this must be the fact that in unvoiced plosives compression gets activated with the onset of voicing only and hence it may not affect the VOT. This also accounts for the results of the study conducted by Moore et al., (2004) where it is reported that there is no effect of time constant on speech intelligibility. These results also validate the results of the study conducted by Jerlvall and Lindblad (1978) that, no notable difference in speech discrimination could be observed for the various combinations of attack and release times for the S/N = 60dB condition, both for the normal subjects as well as for the persons with hearing impairment.

Another reason might be because of the difference in VOT in Kannada and English. English is a two-way language (with voiced and unvoiced plosives) and Kannada is a four-way language (with unaspirated voiced, murmered voiced, unaspirated unvoiced and aspirated unvoiced). Further an unvoiced plosive in the word-initial position in English is aspirated by rule. Hence VOT is longer for unvoiced plosive in English compared to Kannada.

Thus the difference in VOT transformation of voiced and unvoiced plosives in fast and slow AT/RT settings can be one reason for the conflicting results obtained in the previous studies conducted on the effect of compression time constants on speech perception. The conflicting results may be because of the difference in speech stimuli (voiced vs. unvoiced) used in these studies. Hence results of this study figure out VOT transformation as a potential temporal parameter responsible for distortion in hearing aids with compression.

Conclusions

The present study measured attack time and release time of the hearing aids used for the study and estimated the transformation of VOT in hearing aid processed speech for slow and fast compression time constant setting. Results indicated a reduction in VOT for unvoiced plosives in both slow and fast AT/RT setting. For voiced plosives, reduction in VOT was noticed in fast AT/RT setting whereas there was no reduction in slow AT/RT setting. This accounts for reported degradation in speech intelligibility in fast AT/RT settings as reported in the previous studies. The extent of degradation in VOT in fast AT/RT setting can be used as an indicator for specifying the ideal AT/RT setting in fast mode without producing any distortion in hearing aid processed speech. Thus VOT transformation can be used as a factor to find out what constitutes the best compression system in hearing aids.

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References

Gatehouse, Stuart., Naylor, Graham., Elberling, Class. (2006). Linear and nonlinear hearing aid fittings – 1. Patterns of benefit. *International Journal of Audiology, 4*5, 130-152.

Hansen, M. (2002). Effects of multi-channel compression time constants on subjectively perceived sound quality and speech intelligibility. *Ear & Hearing, 23(4)*, 369-380.

Jenstad, L. M., & Souza, P.E. (2005). Quantifying the effect of compression hearing aid release time on speech acoustics and intelligibility. *Journal of speech, language, and hearing research, 48*, 651 – 657.

Jerlvall, L.B., Lindblad, A. C. (1978). The influence of attack time and release time on speech intelligibility. A study of the effects of AGC on normal hearing and hearing impaired subjects. *Scandinavian audiology supplementum, 6*, 341-353.

Kent, R.D., Charles Read. (1995). *The Acoustic Analysis of Speech*. Delhi: AITBS Publishers and Distributors.

Lisker, L., Abramson, A. (1964). A Cross-language study of voicing in initial stops: Acoustical measurements, *Word 20*, 384-422.

Moore, B. C. J., Thomas H. Stainsby, Jose I. Alcantara, Volker Kuhnel. (2004). The effect on speech intelligibility of varying compression time constants in a digital hearing aid. *International Journal of Audiology 43*, 399-409.

Moore, B.C.J., Glasberg, B.R., Stone, M.A., (1991). Optimization of a slow-acting automatic gain control system for use in hearing aids. *British Journal of Audiology, 25*, 171–182.

Moore, B.C.J., & Glasberg, B.R. (1988). A comparison of 4 methods of implementing AGC in hearing aids. *British Journal of Audiology 43*, 399-409.

Nabelek, I.V., & Robinette, L.N. (1977). A comparison of hearing aids with amplitude compression. *Audiology, 16(1)*, 73-76.

Nataraja, N.P., Savithri, S.R., Sreedevi, N., and Sangeetha, M. (2000). *Transformation of the speech of the Hearing Impaired*, Project at AIISH, Mysore funded by Department of Science and Technology, New Delhi.

Neuman, A.C., Bakke, M.H., Mackersie, C., Hellman, S., & Levitt, H. (1998). The effect of compression ratio and release time on the categorical rating of sound quality. *Journal of the Acoustical Society of America, 103(5)*, 2273-2281.

Ole Hau, & Hanne Pernille Andersen. (2012). Hearing aid compression:- Effects of speech, ratio and channel bandwidth on perceived sound quality. *http://www.audiologyonline.com*

Souza, Pameela E. (2002) Effects of Compression on Speech Acoustics, intelligibility, and Sound Quality. *Trends in Amplification, 6*, 131-164.

Shi, Lu-Feng., Karen A. Doherty. (2008). Subjective and objective effects of fast and slow compression on the perception of reverberant speech in listeners with hearing loss. *Journal of speech, language, and hearing research, 51*, 1328 – 1340.

Shobha, N.H., T.G. Thomas & K. Subbarao. (2009). Effect of consonants duration modifications on speech perception in noise. *International Journal of Electronics Engineering, 1(2)*, 179-184.

Stone, M.A. & Moore, B.C.J. (2007). Quantifying the effects of fast-acting compression that affect intelligibility in a competing speech task. *The Journal of the Acoustical Society of America, 121*, 1654-1664.

Stone, M.A., Moore, B.C.J. Alcantara, J.L.,& Glasberg, B.R. (1999). Comparison of different forms of compression using wearable digital hearing aids. *The Journal of the Acoustical Society of America, 106*, 3603-3619.

Van Tasell, D.J. & Trine, T.D. (1996). Effects of single-band syllabic amplitude compression on temporal speech information in nonsense syllables and in sentences. *Journal of Speech and Hearing Research*, *39*, 912-922.

Vonlanthen, Andi., Arndt, Horst. (2007). *Hearing Instrument Technology for the Hearing Healthcare Professional – 3rd Edn.* USA: Thomson Delmar Learning.

EFFECT OF NOISE ON BIOMARK IN INDIVIDUALS WITH LEARNING DISABILITY

[1]Uday Kumar, [2]Akshay Raj Maggu & [3]Mamatha N. M.

Abstract

Several studies have reported poor temporal processing and speech-in-noise problems in children with learning disability (LD) (Chandrasekaran, Hornickel, Skoe, Nicol & Kraus, 2009; Hayes, Warrier, Nicol, Zecker & Kraus, 2003). Electrophysiological techniques such as speech ABR have been used (King, Warrier, Hayes & Kraus, 2002; Russo, Nicol, Zecker, Hayes & Kraus, 2005) to determine the auditory processing deficits in children with LD. The present study utilised BioMARK to find out the differences in speech sound processing in children with LD, in quiet and noise. Fifteen children in the age range of 8 to 12 years were selected for the study which included 5 children with LD and 10 typically developing children. All the 15 participants had a normal peripheral hearing sensitivity and they underwent BioMARK response testing with 40 ms /da/ stimulus. The stimulus was presented in quiet as well as in presence of white noise (+30 dB SNR) ipsilaterally. The peaks were marked as wave V, A, C, D, E, F, and O. The waveforms were converted into ASCII codes and processed using Brainstem Toolbox on Matlab vR2009B (Skoe & Kraus, 2010). Amplitudes of the formant of fundamental frequency, first formant and higher frequency were obtained and compared. Results showed a significant difference (p<0.05) in latency of the peaks V, A, D, E, F and O, of BioMARK in children with LD as compared to typically developing children. This was true for both quiet and noise conditions. Also, a significant difference (p<0.05) in the amplitudes of various formants was found in noise condition for children with LD and typically developing children. So, it can be concluded that there is a problem in decoding of information in presence of noise which is more pronounced in children with LD. Hence, other management strategies along with environmental modifications should be employed.

Keywords: *Noise, Learning disability.*

Speech perception in daily life places a lot of demands on the auditory system. For an accurate representation of the speech, rapidly changing spectral information and its separation from background noise is absolutely necessary. Usually, most of the individuals are able to face and get through these challenges easily. However, there are groups of population who find it extremely difficult to understand speech in presence of noise. One such group consists of individuals with learning disability (LD). LD, according to the Individuals with Disabilities Education Improvement Act (2004) is a disorder which may involve deficits in basic psychological processes required for understanding or for using spoken / written language. These problems may manifest themselves as deficit in academic abilities. Several researchers have documented poor auditory processing in children with learning problems (Cestnick & Jerger, 2000; Farmer & Klein, 1995; Hari & Kiesila, 1996; Nagarajan et al., 1999; Tallal & Piercy, 1974). One of the major auditory processing problems in these children has been listening in background noise (Bellis, 1996; Breedin et al., 1989; Chermak & Musiek, 1997; Cunningham, Nicol, Zecker & Kraus, 2001; Katz, 1992; Katz et al., 1992).

Researchers have reported an effect of noise on brainstem (King et al., 2002) as well as cortical responses (Martin et al., 1999; Whiting et al., 1998; Wible, Nicol & Kraus, 2002). In few cases, there have been reports of a presence of neurobiological abnormalities leading to auditory processing deficits (Cunningham et al., 2001; Nagarajan et al., 1999; Temple et al., 2000) while in others the cause has been unknown. Many investigators have attributed the poor reading skills in children to their inability to perceive in presence of noise (Godfrey et al., 1981; McBride-Chang, 1996; Reed, 1989).

To overcome the dreadful effects of noise on speech comprehension, several researchers (Bellis, 2003, Chermak & Musiek, 1997; Ferre, 2006) have suggested a delivery of signal at a higher signal-to-noise ratio (SNR). This is expected to benefit these children in classroom conditions where SNR is poor. The American

[1]Student, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: kumaruday70@gmail.com, [2]Research Officer, AIISH, Mysore-06, Email: akshay_aiish@yahoo.co.in & [3]Lecturer in Audiology, AIISH, Mysore-06, Email: mamms_20@gmail.com

(ASHA) (2005) recommended an SNR of +15 dB in classroom conditions.

There are many behavioural tests that can help in obtaining the auditory processing status of an individual but since many of these tests are not modality specific and are cognitively based (Cacace & McFarland, 2009), it becomes difficult to rely on their results, especially in children. On the other hand, there are electrophysiological tools which do not require much participation from an individual.

The present study was aimed at understanding the differences in typically developing children and children with LD in handling rapid speech signals using a BioMARK response. The study also aimed to compare the BioMARK responses between the two groups in presence of ipsilateral white noise at a higher SNR (+30 dB SNR) than recommended by ASHA (2005) for classroom situations.

Method

Participants

Ten typically developing children (20 ears) and 5 children with LD (10 ears) in the age range of 8 to 12 years were selected for the study. All the 15 participants had a pure tone air conduction and bone conduction threshold within 15 dB HL, from 250 Hz to 8000 Hz and 250Hz to 4000Hz, respectively. All of them had a type A tympanogram with acoustic reflex thresholds ranging from 80 to 100 dB HL and speech identification scores greater than 90% in both ears. It was ensured that all participants had normal Intelligence Quotients between 90 to 110 as measured on Raven's Coloured Progressive Matrices (Raven, 1956). Children with LD were selected based upon the diagnosis of a speech language pathologist.

Instrumentation and environment

A calibrated dual channel audiometer (Orbiter 922, GN Otometrics, Taastrup, Denmark) was used for testing pure tone air conduction, bone conduction and speech identification testing. Headphones used for this purpose were TDH-39 housed in Mx-41/AR cushions and bone vibrator was Radioear B-71. A calibrated immittance meter (GSI Tympstar; Grason Stadler, Eden Prairie, MN) was used for testing the middle ear function. A 'Biologic Navigator Pro' evoked potential instrument was used for recording click evoked auditory brainstem response (ABR) and BioMARK response. All evaluations were carried out in an acoustically treated two-room sound suite fitted to ANSI S3.1 (1991) standards.

Stimuli

For a click ABR, a click stimulus of 100 µs was utilised while for a BioMARK response 40 ms /da/ stimulus recommended by King et al. (2002) was used. This stimulus was available in the 'Biologic Navigator Pro' evoked potential instrument.

Procedure

After obtaining the demographic details of the participants, they were subjected to pure-tone air conduction, bone conduction testing, speech audiometry and acoustic immittance measurement. Further, the participants underwent the click ABR and BioMARK testing according to the protocol provided in Table 1. The pattern of testing followed from click ABR testing, to BioMARK testing in quiet to BioMARK testing with an ipsilateral white noise. This white noise was provided ipsilaterally through the evoked potential system at 50 dB SPL in a way so that signal to noise ratio is maintained at 30 dB SNR.

Table 1: *Protocols for click ABR and BioMARK testing*

	Stimulus	Click ABR	BioMARK /da/
Stimulus parameters	Duration	100 µs	40 ms
	Intensity	80 dB SPL	80 dB SPL
	Polarity	Alternating	Alternating
	Repetition rate	11.1/sec	9.1/sec
	No. of stimuli	2000	3000
	Analysis time	10 ms	74.67 ms (15 ms pre-stimulus, 59.67 ms post-stimulus)
Acquisition parameters	Filters	100 - 3000 Hz	100 - 3000 Hz
	Electrode placement	Non-inverting (+ve): vertex; inverting (-ve): Test ear mastoid; ground: Non-test ear mastoid	Non-inverting (+ve): vertex; inverting (-ve): Test ear mastoid; ground: Non-test ear mastoid
	Transducers	Biologic Inserts	Biologic Inserts

Two recordings for each waveform were obtained to ascertain the reliability and these waveforms were 'weighted added' using the BIOLOGIC system software. On this waveform, the peaks were marked as V, A, C, D, E, F and O. The identification of peaks was carried out by two audiologists (other than the authors). Further, these waveforms were converted into ASCII codes using the AEP to ASCII conversion software. These ASCII codes were further processed in the Brainstem Toolbox developed by Skoe and Kraus (2010) using Matlab vR2009B. This helped in obtaining the fast fourier transformation (FFT) of the waveforms. FFT led to obtaining the spectral amplitude at the fundamental frequency (F0) 103-120 Hz, first formant (F1) 455-720 Hz and second formant (F2) 720-1154 Hz.

Analyses

Both the groups were compared for the latencies of the peaks as well as the spectral amplitude obtained in both quiet and noise conditions. Descriptives (mean and standard deviation) were obtained for both the groups for both the ears. Mann Whitney U test was carried out to know the differences between the two groups in terms of latencies and amplitude with and without the noise. Wilcoxon test was performed to know the differences within the group in terms of latencies and amplitude, with and without the noise.

Results

The mean and standard deviations for the latencies of wave V, A, D, E, F, O were obtained as depicted in Table 1. Wave C was not considered for further statistical treatment as it was absent in 22 out of 30 ears tested.

The mean latencies as observed in Table 1 reveal that there is a delay in latency of all the peaks in children with LD group as compared to the typically developing children. It can also be noticed that with an introduction of noise with the stimulus, there was a shift in latencies of all the peaks. This happened for both the groups but slightly more for children with LD group for wave V, A and D.

Table1: *Mean and standard deviations of the latencies of wave V, A, D, E, F and O for the typically developing and children with LD group across the quiet and noise conditions*

Wave		Condition							
		Quiet				Noise			
		Typically developing		Children with LD		Typically developing		Children with LD	
	Ear	Mean (ms)	S.D.	Mean (ms)	S.D.	Mean (ms)	S.D.	Mean (ms)	S.D.
V	Right	6.66	0.14	7.66	0.42	7.86	0.47	8.80	0.39
	Left	6.60	0.09	7.98	0.36	7.55	0.52	9.05	0.24
A	Right	7.35	0.17	8.28	0.48	8.68	0.31	9.92	0.45
	Left	7.36	0.12	8.56	0.14	8.65	0.54	10.32	0.51
D	Right	22.64	0.23	25.22	0.78	23.94	0.31	28.62	0.56
	Left	22.60	0.25	26.96	1.36	22.60	0.26	29.36	1.87
E	Right	30.83	0.19	35.26	1.28	32.31	0.76	35.26	1.28
	Left	30.83	0.20	38.30	0.63	30.83	0.20	38.30	0.63
F	Right	39.39	0.18	41.23	0.94	39.39	0.18	41.23	0.94
	Left	38.37	3.12	42.72	1.41	38.37	3.13	42.72	1.41
O	Right	47.62	0.20	52.86	2.41	47.63	0.20	52.86	2.41
	Left	47.60	0.12	51.64	2.54	47.60	0.12	51.64	2.54

Further inferential statistics were also carried out. Mann Whitney U test was done to know if there was any difference between the groups in both quiet and noise condition. It was found that the LD group was significantly different ($p<0.001$) from the typically developing children both in quiet and the noise condition. In Figure 1(a), it can be seen that for both the ears there is a delay in latency for the children with LD for all the peaks, in quiet condition. In figure 1(b), a similar trend can be appreciated for the noise condition. Wilcoxon signed ranks test revealed that there was a significant difference ($p<0.05$) in the latencies of all the peaks with introduction of noise. This was true for both the experimental and control group.

The amplitudes of Fo, F1 and higher frequency (HF) were obtained from processing the ASCII codes of waveforms into Brainstem Toolbox. These amplitudes were further compared for both the groups and conditions as depicted in Table 2. Mann Whitney U test also revealed a difference between the two groups for the amplitude for Fo, F1 and higher frequency.

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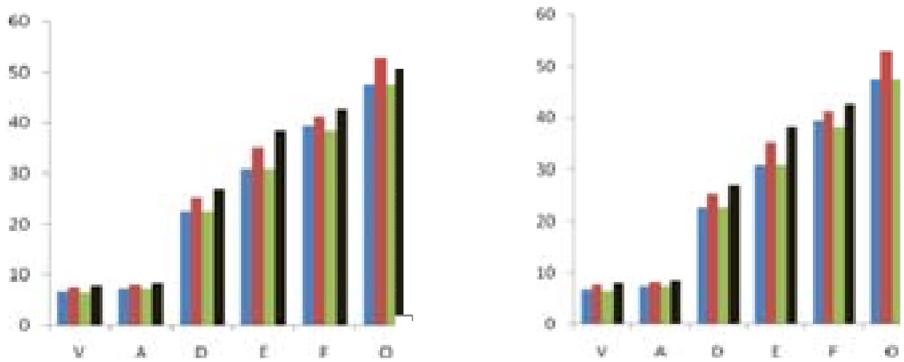

Figure1: *Comparison of latencies of the BioMARK response peaks across experimental and control group in (a) quiet condition (b) noise (+30 dB SNR)*

Table 2: Depicting the amplitude (in µV) for the various frequencies across the different groups and conditions

Frequency	Ear	Typically developing		Typically developing		Typically developing (+30dB SNR)		Typically developing (+30 dB SNR)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fundamental	Right	5.39	0.98	4.83	1.02	5.20	1.02	2.48	1.06
frequency (Fo)	Left	4.81	1.11	2.97	0.96	4.78	1.02	2.25	1.02
First formant	Right	1.12	0.45	0.96	0.43	1.11	0.33	0.33	0.28
(F1)	Left	0.99	0.53	0.78	0.29	0.97	0.58	0.24	0.22
Higher frequency	Right	0.31	0.13	0.22	0.11	0.32	0.15	----	----
(HF)	Left	0.22	0.12	0.20	0.19	0.19	0.11	----	----

This difference was persistent among the groups for both the conditions. As it can be observed from Table 2, there is a regular decrease in the amplitude of Fo, F1 and higher frequency from control to experimental group and quiet to noise condition. Wilcoxon signed ranks test was carried out and it was found that there was a significant difference ($p<0.05$) in amplitude in quiet and noise in both the groups. The decrease in amplitude was observed in both the groups but in children with LD, low amplitudes were noticed for Fo and F1 while the amplitudes at higher frequencies were too low to be recorded.

Discussion

Previously, there have been reports of slow temporal processing and poor speech-in-noise perception in children with LD (Bellis, 1996; Ferre, 2006; King et al., 2002; Russo et al., 2005). Both brainstem and cortical evoked potentials have been utilised in the past to know the difference in auditory processing between children with LD and typically developing children. In the present study, through BioMARK speech ABR responses, it has been found that there is an increase in latency of all the peaks of speech ABR in children with LD. These results are in consonance with those of the (Cunningham et al., 2001; King et al., 2002) who also noted a delay in latency for speech ABR peaks. This has been attributed to the temporal processing deficit in the children with LD.

Although, a number of studies have investigated nature of speech ABR in quiet conditions, there is a dearth of literature studying the effect of ipsilateral noise on speech ABR. The present study found a further increase in latency of the peaks of speech ABR. It was found that noise affected the typically developing children too, but its effect on children with LD was much more. After analysing the amplitude of Fo, F1 and F2, it was found that there was a great reduction of amplitude in children with LD in both quiet and noise (+30 dB SNR). The amplitude for higher frequencies was distorted to the maximum extent in this group. Comparatively, the group with typically developing children did not have a significant reduction in amplitude at all the formant frequencies at +30 dB SNR. This shows that children with LD are more prone to the hazardous effects of noise.

In order to overcome the effects of noise and enhance the auditory processing, several investigators (Bellis, 2003; Chermak & Musiek, 1997; Ferre, 2006) have recommended an increase in SNR to be provided in classroom conditions. ASHA (2005) has recommended +15 dB SNR to be used in classrooms. In this preliminary study, it is evident that even at +30 dB SNR, children with LD could not benefit much. Hence, other management strategies to improve the auditory processing in such individuals should be undertaken. Direct remediation activities (Bellis, 1996) like noise desensitisation training (Katz & Burge, 1971; Maggu & Yathiraj, 2011) can be promising in this regard.

Conclusions

From the findings of this preliminary study, it can be concluded that children with LD exhibit problems in speech sound processing. This problem is aggravated in the presence of noise. A higher SNR might not be an exact solution for this population. Hence, other management strategies should also be utilized.

References

ANSI S3.1 (1991). American National Standards Institute (1991). *Maximum permissible ambient noise for audiometric test rooms.* ANSI S3.1-1991. New York: American National Institute.

American Speech- Language- Hearing Association. (2005). *Guidelines for addressing acoustics in educational settings (guidelines)*. Retrieved from www.asha.org/policy.

Bellis, T. J. (1996). *Assessment and management of Central Auditory Processing Disorders in the educational setting: from science to practice*. San Diego, CA: Singular.

Bellis, T. J. (2003). *Central auditory processing in the educational setting: From science to practice* (2nd Ed.). Clifton Park, NY: Thomas–Delmar Learning.

Breedin, S. D., martin, R. C., Jerger, S. (2000). Distinguish auditory and speech-specific perceptual deficits. *Ear and Hearing, 10*, 311-317.

Cacace, A. T. & McFarland, D. J. (2009). Modality specificity and auditory processing disorders.

Cacace,A.T.& McFarland,D.(2009). *Controversies in central auditory processing disorder*. (pp199-216).San Diego: Plural publishing.

Cestnick, L. & Jerger, J. (2000). Auditory temporal processing and lexical/nonlexical reading in developmental dyslexics. *Journal of American Academy of Audiology, 11*, 501-513.

Chandrasekaran, B., Hornickel, J., Skoe, E., Nicol, T. & Kraus, N (2009). Context-dependent encoding in the human auditory brainstem relates to hearing speech in noise: Implications for developmental dyslexia. *Neuron, 64,* 311-319.

Nagarajan, S., Mahncke, H., Salz, T., Tallal, P., Roberts, T. & Merzenich, M. M. (1999). Cortical auditory signal processing in poor readers. *Proceedings of National Academy of Sciences, 96*, 6483-6488.

Chermak, G. D. & Musiek, F. E. (1997). *Central auditory processing disorders: new perspectives.* San Diego, CA: Singular publishing.

Cunningham, J., Nicol, T., Zecker, S. G., Kraus, N. (2001). Neurobiologic responses to speech in noise in children with learning problems: deficits and strategies for improvement. *Clinical Neurophysiology, 112,* 758-767.

Farmer, M. E. & Klein, R. (1995). The evidence for a temporal processing deficit linked to dyslexia: a review. *Psychon Bulletin review, 2,* 460-493.

Ferre, J. M. (2006). Management strategies for APD. In T. K. Parthasarathy (Ed.). *An introduction to auditory processing disorders in children* (pp. 167-169). New Jersey: Lawrence Erlabaum Associates.

Godfrey, J. J., Syrdal-Lasky, A. K., Millay, K. K. & Knox, C. M. (1981). Performance of dyslexic children on speech perception tests. *Journal of Experimental Child Psychology, 32,* 401-424.

Hari, R. & Kiesila, P. (1996). Deficit of temporal auditory processing in dyslexic adults. *Neuroscience letters, 205,* 138-140.

Hayes, E., Warrier, C. M., Nicol, T., Zecker, S. & Kraus, N. (2003). Neural plasticity following auditory training in children with learning problems. *Clinical Neurophysiology, 114,* 673-684.

Katz, J. (1992). Classification of auditory disorders. In: Katz, J., Stecker, N. and Henderson, D (Eds). *Central auditory processing:A transdisciplinary view.* St. Louis, MO: Mosby, 81-92.

Katz, J., & Burge, C. (1971). Auditory perception training for children with learning disabilities. *Menorah Medical Journal, 2,* 18-29.

Katz, J., Smith, P. S. & Kurpita, B. (1992). Categorizing test findings in children referred for auditory processing deficits. *SSW rep, 14,* 1-6.

King, C., Warrier, C. M., Hayes, E. & Kraus, N. (2002). Deficits in auditory brainstem pathway encoding of speech sounds in children with learning problems. *Neuroscience letters, 319*, 111-115.

Maggu, A. R., & Yathiraj, A., (2011). Effect of noise desensitization training on children with poor speech-in-noise scores. *Canadian Journal of Speech Language Pathology and Audiology, 35 (1),* 56-63.

Martin, B. A., Kurtzberg, D. & Stapells, D. R. (1999). The effects of decreased audibility produced by high-pass noise masking on N1 and the mismatch negativity to speech sounds /ba/ and /da/. *Journal of Speech Language and Hearing Research, 42,* 271-286.

McBride-Chang, C. (1996). Models of speech perception and phonological processing in reading. *Child Development, 67,* 1836-1856.

Raven, J. C. (1956). *Coloured progressive matrices*. Lewis and Co.: London.

Reed, M. A. (1989). Speech perception and the discrimination of brief auditory cues in reading disabled children. *Journal of Experimental Child Psychology, 48,* 270-292.

Russo, N. M., Nicol, T. G., Zecker, S. G., Hayes, E. A., & Kraus, N. (2005). Auditory training improves neural timing in the human brainstem. *Behavioural Brain Research, 156,* 95–103.

Skoe, E. & Kraus, N. (2010). Auditory brain stem response to complex sounds: a tutorial. *Ear and Hearing, 31*(3), 302-324.

Tallal, P. & Piercy, M. (1974). Developmental aphasia: rate of auditory processing and selective impairment of consonant perception. *Neuropsycholgia, 12,* 83-93.

Temple, E., Poldrack, R. A., Protopapas, A., nagarajan, S., Salz, T., Tallal, P., et al. (2000). Disruption of the neural response to rapid acoustic stimuli in dyslexia: evidence from functional MRI. *Proceedings of National Academy of Sciences, 97,* 13907-13912.

Whiting, K. A., Martin, B. A. & Stapells, D. R. (1998). The effects of broadband noise masking on cortical event-related potentials to speech sounds /ba/ and /da/. *Ear and Hearing, 19,* 218-231.

Wible, B., Nicol, T. & Kraus, N. (2002). Abnormal neural coding of repeated speech stimuli in noise in children with learning problems. *Clinical Neurophysiology, 113* (2), 485-494.

PHYSIOLOGICAL BASES OF THE ENCODING OF SPEECH EVOKED FREQUENCY FOLLOWING RESPONSES

[1]Nike Gnanateja G., [2]Ranjeet Ranjan, & [3]Sandeep M.

Abstract

Many studies have shown that fundamental frequency (F0) is represented in the speech evoked Frequency Following Response (FFR), however, it is not clear as to what aspect of the stimulus is the basis for the F0 coding. The energy at the Fo alone is less likely to be the basis, as our ear is less sensitive to very low frequencies which is evident from the very high RETSPL. Thus, the present study was taken up to analyse the independent role of high frequency harmonics and stimulus envelope in the encoding of the speech evoked FFRs. In the Experiment 1 of the present study, FFRs were elicited with a high-pass filtered syllable and compared with that of the unfiltered syllable. Results showed that the FFRs elicited for the 2 stimuli were not different in spectrum. This finding implies that the FFRs are primarily coded by the higher harmonics (frequencies beyond F2), and the lower harmonics contribute less for the coding of F0 and the first formants. However, as the envelope was same in both the stimuli, it cast a doubt that the responses obtained were because of the envelope and not the lower harmonics. To verify this, Experiment 2 was carried out, wherein FFRs were recorded to stimuli with envelope of the vowel portion removed without altering the fine structure. The FFRs elicited by the fine-structure stimulus revealed that the F0 amplitude was significantly lower compared to the original stimulus which implies that envelope is the key parameter for the coding of FFRs.

Key Words: *Brainstem pitch encoding, envelope following responses, fine-structure encoding*

Auditory brainstem responses (ABR) elicited with speech stimuli have received much attention in the last two decades. The ABR to a speech stimulus has basically three main components, the onset response, the frequency following response (FFR) and the offset response (Greenberg, 1980; Galbraith Arbagey, Branski, Comerci, & Rector, 1995; Skoe & Kraus, 2010). The FFR has received considerable attention in the last decade. The FFR is a sustained auditory evoked potential which mimics the oscillations in the stimulus and has been found to be originating primarily from the inferior colliculi and the rostral brainstem structures (Cunningham, Nicol, Zecker, Bradlow, & Kraus, 2008; Greenberg, Marsh, Brown, & Smith, 1987; Krishnan & Gandour, 2009; Russo, Nicol, Musacchia, & Kraus, 2004). The FFRs have been recorded for stimuli like, vowels, consonant-vowel syllables, low frequency tones, modulated tones and also to instrumental music. The consonants, sparing the continuants, in speech do not contribute much for the FFR, rather they elicit onset responses. On the other hand, sustained vowels elicit FFRs that mimic the stimulus.

There has been considerable research on the types of stimuli that are most suitable for recording the FFRs, the results of which have thrown light on the physiological bases of the FFRs. Dau (2003) demonstrated that FFRs to low frequency tones, represent synchronized brainstem activity mainly stemming from mid and high-frequency excitation of the basilar membrane, and not from units tuned to frequencies around the signal frequency. They hypothesized that the temporal envelope conveyed by the higher frequency regions might be more responsible for the generation of the FFR than the characteristic frequency itself. Contrary to Dau (2003), Greenberg, Marsh, Brown, & Smith (1987) recorded FFRs for missing fundamental stimuli with varied stimulus envelopes and demonstrated that the FFRs are not a result of a phase locking to the stimulus envelope. Thus, discrepancies exist in literature about the bases for coding of FFRs.

Need and specific aim of the study

The syllable /da/ of 40 millisecond duration having a fundamental frequency of nearly 105 Hz and five formants has been extensively used to record the speech evoked FFR (Krizman, Skoe, & Kraus, 2010; Abrams, Nicol, Zecker, & Kraus, 2006; Hornickel, Skoe, & Kraus, 2009). Most of these studies have quantified the spectrum of FFR in terms of its amplitude at fundamental frequency (F0) and the first two formant (F1 and F2) frequency ranges. Although, it is clear from these studies that Fo is represented in the elicited FFR, it is not clear as

[1]Research Officer, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: nikegnanateja@gmail.com, [2]Research Officer, AIISH, Mysore-06, Email: ranjanbs3@yahoo.co.in & [3]Lecturer in Audiology, AIISH, Mysore-06, Email: msandeepa@gmail.com

to what aspect of the stimulus is the bases for the F0 coding. The energy at the Fo is less likely to be the bases as our ear is less sensitive to very low frequencies, which is evident from the very high Reference Equivalent Sound Pressure Level. Psychophysical theories of pitch perception have demonstrated that it is the higher harmonics which determine the pitch of the signal (Plomp, 1967; Moore & Peters, 1992). Objective correlates of this have been demonstrated by Greenberg et al. (1987) and Chambers, Feth and Burns (1986) using harmonic complexes where they showed that the harmonics in the signal help represent the fundamental in the FFR. They further concluded that the FFR follows the fine structure alone and is not related to the waveform envelope. However a close look at the waveforms in their study shows considerable difference in the amplitude of the FFR with changes in the stimulus envelope. Hence, the role of stimulus envelope, along with the fine structure was suspected to be the bases for FFR and this needed experimental investigation.

Thus, the present study was taken up to analyse the independent role of higher harmonics and stimulus envelope on the speech evoked FFRs.

Method

The study was conducted as two experiments. Experiment 1 was conducted to analyse the role of the higher harmonics in the speech evoked FFRs while the Experiment 2 was conducted to analyse the role of the stimulus envelope in the speech evoked FFRs and to help explain the results of Experiment 1.

Experiment 1

Participants

Thirteen adults in the age range of 18 to 24 years participated in the first experiment. All the participants had normal hearing sensitivity, middle ear functioning and speech perception in noise, on preliminary evaluations. Preliminary evaluations included puretone audiometry, immittance evaluation and, the assessment of speech identification scores at 0 dB signal-to-noise ratio. The participants had pure tone hearing thresholds of 15 dBHL or lesser, in the octave frequencies between 250 to 8 kHz on air conduction testing. They had Type-A tympanogram with normal acoustic reflex thresholds ruling out the presence of any middle ear pathology (Jerger, Anthony, Jerger, & Mauldin, 1974). Their speech identification scores were more than 60% in both ears, in the presence of speech noise.

Test Stimuli

The main stimulus used in the study was a synthetic 40 msec /da/ syllable, same as the one used by Abrams, Nicol, Zecker, and Kraus (2006). A filtered derivative of the /da/ stimulus was prepared by high pass filtering the original /da/ stimulus using a sixth order butterworth filter with a cut-off frequency of 1700 Hz in Adobe Audition, version 3.0. The cut-off frequency corresponded to the second formant frequency of the signal. The waveforms and spectra of the two stimuli are shown in Figure 1. The frequency following responses for the original /da/ stimulus and the filtered /da/ stimulus were elicited with a stimulation rate of 10.9/s at an intensity level of 80 dBSPL presented in alternating polarity.

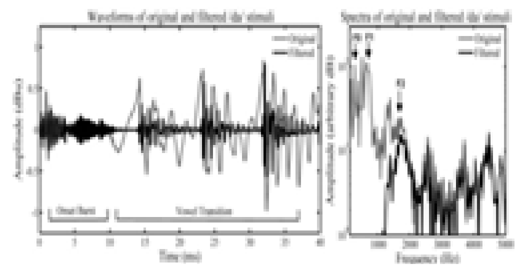

Figure 1*: The waveforms and the spectra of the original and the filtered /da/ stimuli*

Test Procedure

The actual test procedure involved recording of the speech evoked ABR using different stimuli. The participants were comfortably seated on a reclining chair. Before starting the recording, low absolute and relative electrode impedance were ensured. Biologic Navigator Pro (version 7) was used to record the FFRs. The stimulus locked responses were acquired between -11.2 to +52.8 msec in a vertical (Cz-C7) electrode montage. The responses elicited by 2000 alternate polarity stimuli were averaged and replicated. The stimuli were presented at 10.9/s rate through ER-3A insert phones at 80 dBSPL.

The waveforms were spectrally analysed using Brainstem toolbox 2010 (Skoe & Kraus, 2010). The amplitudes at the fundamental frequency (F0 = 103-121 Hz), first formant frequency (F1 = 454-719 Hz) and second formant frequency (F2 = 721-1155 Hz) were analysed in the region of 11 to 45 milliseconds. The FFR spectral amplitudes thus obtained, were scaled into arbitrary decibel values and compared across the different stimuli.

Results

All the statistics in the data were performed using Statistical Package for Social Sciences, version-17 (SPSS, V.17). The data was analysed on the Kolmogorov Smirnov which showed that the data was normally distributed. Multiple paired t-tests were used to compare the spectral amplitudes at F0, F1, and F2 of the FFRs elicited by original /da/ and filtered /da/. The mean and standard deviation of the spectral amplitudes for the two stimuli are given in Table 1. Results of paired t-test (Table 2) revealed no significant differences between the amplitudes at F0, F1 and F2 for the FFRs elicited by the original and filtered stimuli.

Table 1: *Mean and standard deviation of F0, F1, and F2 amplitudes (arbitrary dB) for the FFRs elicited by original /da/ and filtered /da/ and the results of paired t-test*

Parameter	Stimulus /da/	Mean (N = 13)	SD	t	df	p
F0	Original	5.69	2.25	0.76	12	0.47
	Filtered	5.23	2.62			
F1	Original	0.70	0.34	1.17	12	0.27
	Filtered	0.85	0.22			
F2	Original	0.29	0.12	0.78	12	0.45
	Filtered	0.32	0.07			

Experiment 2

Participants

Fifteen participants in the age range of 18 to 27 years participated in this experiment. The subject selection criteria were the same as that in Experiment 1.

Test Stimuli

The Hilbert envelope of the vowel portion of the original /da/ stimulus was extracted. The stimulus was then divided by its Hilbert envelope so as to obtain the fine structure of the vowel. This was achieved using a customized script on a MATLAB platform (version 7.14). Thus, the new stimulus was same as the original stimulus in terms of the burst portion till the vowel onset, and dissimilar in terms of the envelope of the vowel portion. This new stimulus was operationally termed fine-structure /da/. The waveforms and the spectra of the original and the fine-structure /da/ are shown in Figure 2.

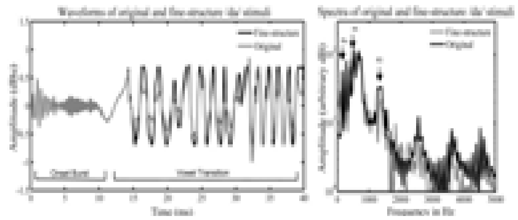

Figure 2*: Waveforms and spectra of original /da/ and fine-structure /da/.*

The stimulus and recording parameters, as well as analysis methods were same as that used in Experiment 1. Kolmogorov-Smirnov test revealed that the data in all the parameters were normally distributed. The spectral amplitudes of the FFRs at F0, F1 and F2 were compared between the stimuli on multiple paired t-tests.

Results

The mean and standard deviation of the spectral amplitudes of FFRs elicited by the two stimuli are given in Table 3. Table 3 also gives the results of paired t-test. Results revealed large statistically significant difference ($p<0.000$) between the amplitudes at F0 for the FFRs elicited by the original and fine-structure /da/. There was also a smaller, however, significant difference in the ampitudes at F1 ($p = 0.024$) and F2 ($p = 0.033$) between the two stimuli.

Table 3: *Mean and standard deviation of amplitudes (arbitrary dB) at F0, F1, and F2 for the FFRs elicited by original /da/ and fine-structure/da/, and the results of paired t-test*

Parameter	Stimulus /da/	Mean (N = 13)	SD	t-value	df	Level of significance
F0	Original	6.94	2.86	5.38	14	0.00
	Fine-structure	2.72	1.55			
F1	Original	1.69	0.63	2.53	14	0.02
	Fine-structure	1.47	0.49			
F2	Original	0.47	0.47	2.36	14	0.03

Discussion

The onset responses were not analysed as it was not the focus of the study. The FFRs elicited by the filtered stimulus were similar to those elicited by the original stimulus as can be seen from Figure 3. Also there was no difference in the FFRs based on the spectral analysis. Thus, the elimination of the lower harmonics in the /da/ stimulus did not affect the FFRs appreciably.

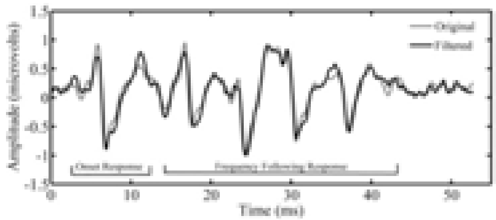

Figure 3: *Grand average FFRs elicited by the original /da/ and filtered /da/.*

This representation of F0 and lower formants in the FFRs, while the low frequency spectral components were removed, may be because of two probable mechanisms: (1) as proposed by the temporal models of pitch perception (Terhardt, Stoll, & Seewan, 1974), the decoding of the harmonic relationship in the higher harmonics at the brainstem level may be aiding to code F0, F1 and F2. (2) The residual low frequency envelope information from the higher harmonics helped code the FFRv as shown in Figures 4 and 5.

Experiment 2 was carried out to verify which of these two explanations holds good. The envelope of the vowel portion of the stimulus was smeared to obtain the fine structure of the vowel portion, while the burst portion of the stimulus was left unaltered.

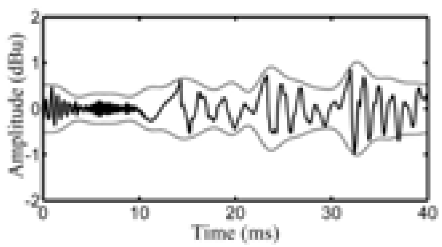

Figure 4*: Waveform of the original /da/ (black) with schematic representation of the stimulus envelope (red).*

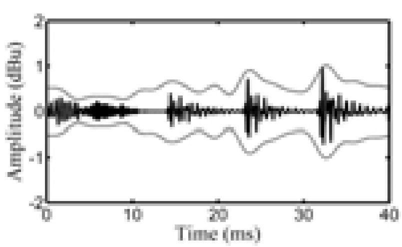

Figure 5*: Waveform of the filtered /da/ (black) with schematic representation of the stimulus envelope (red) of original /da/*

The FFRs elicited by the fine-structure /da/ showed that the Fo amplitude was significantly lower compared to those elicited by the original /da/. The burst portion in the fine-structure /da/ stimulus elicited onset responses exactly similar to the onset responses elicited by the original /da/. However, the FFRs elicited by the fine-structure /da/ were considerably different in the morphology and the number of peaks observed. The grand averaged FFRs for the two stimuli can be seen in Figure 6.

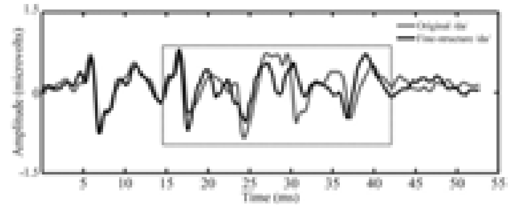

Figure 6: *Grand average FFRs elicited by the original /da/ and the fine structure /da/ stimuli*.

The grey marked area shows the FFR region which varied for the two stimuli. The results suggest that the strikingly similar FFRs to the two stimuli in Experiment 1 can be attributed to the similarity in the envelope between the two stimuli used as can be seen from Figure 4 and Figure 5. This finding gives strong evidence to the second explanation proposed, i.e. the FFRs are basically coded by the stimulus envelope as also proposed by Gardi, Merzenich, and McKean (1979) and Stillman, Crow, and Moushegian (1987). Additionally, the first experiment suggests that the lower harmonics do not help significantly in the coding of the FFRs. The lower harmonics are 'resolved' and the combined output of the resolved harmonics from the cochlea has been demonstrated to have poor temporal coherence (Dau, 2003) and thus did not contribute to the coding of the FFRs which are primarily the envelope following responses. However, the higher harmonics being 'unresolved' produce a temporally coherent cochlear output and help in coding of theses envelope following responses.

Conclusions

The F0, F1 and F2 information represented in the FFRs are primarily the result of phase locking to the stimulus envelope mediated by the precise temporal coding of higher harmonics. However, the role of the lower harmonics and the energy at the fundamental frequency itself appears to be somewhat limited. From these findings, one can also infer that energy below F2 need not be synthesized while generating the stimulus for a study that aims to track the brainstem encoding of pitch.

Acknowledgements

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References

Abrams, A. A., Nicol, T., Zecker, S. G., & Kraus, N.(2006). Auditory Brainstem timing predicts cerebral asymmetry for speech. *The Journal of* Neuroscience, 26(43), 11131-11137.

Chambers, R., Feth, L., & Burns, E. (1986). The relationship between the human frequency following response and the low pitch of complex tones. *Journal of the Acoustical Society of America, 75*, S81(A).

Cunningham, J., Nicol, T., Zecker, S. G., Bradlow, A., & Kraus, N. (2001). Neurobiologic responses to speech in noise in children with learning impairment: deficits and strategies for improvement. *Clinical Neurophysiology, 112*,758-767.

Dau, T. (2003). The importance of cochlear processing for the formation of auditory brainstem and frequency following responses. *Journal of the Acoustical Society of America, 113*, 936-50.

Galbraith, G. C., Arbagey, P. W., Branski, R., Comerci, N., & Rector, P. M. (1995). Intelligible speech encoded in the human brainstem frequency following response. *Neuroreport, 6*, 2363-2367.

Gardi, J., Mezenich, M., & McKean, C. (1979). Origins of the scalp-recorded frequency-following response in the cat. *Audiology*, *18*, 358-381.

Greenberg, S. (1980). Temporal neural coding of pitch and vowel quality. *Working Papers in phonetics. WPP-52*. Department of Linguistics, UCLA

Greenberg, S., Marsh, J.T., Brown, W.S. & Smith, J.C. 1987. Neural temporal coding of low pitch. I. Human frequency-following responses to complex tones. *Hearing Research, 25*, 91-114.

Hornickel, J., Skoe, E. & Kraus, N. (2009). Sub-cortical laterality of speech encoding. *Audiology and Neuro-otology*, *14*, 198-207.

Jerger, J., Anthony, L., Jerger, S., & Mauldin, L. (1974). Studies in impedance audiometry, III: Middle ear disorders. *Archives of Otolaryngology, 99,* 409-413.

Jewett, D. L., Romano, M. N., & Williston, J. S. (1970). Human auditory evoked potentials: possible brainstem components detected on the scalp. *Science*, 167, 1517-1518

Krishnan, A., & Gandour, J. T. (2009). The role of the auditory brainstem in processing linguistically-relevant pitch patterns. *Brain & Language*, *110*, 135-148

Krizman, J., Skoe, E., & Kraus, N. (2010). Stimulus rate and subcortical auditory processing of speech. *Audiology & Neurotology*, *15*, 332-342.

Moore, B. C. J., & Peters, R. W. (1992). Pitch discrimination and phase sensitivity in young and elderly subjects and its relationship to frequency selectivity. *Journal of the Acoustical Society of America, 91*, 2881-2893.

Plomp, R. (1967). Pitch of complex tones. *Journal of Acoustical Society of America, 41,* 1526-1533.

Russo, N., Nicol, T., Musacchia, G., & Kraus, N. (2004). Brainstem responses to speech syllables. *Clinical Neurophysiology, 115*, 2021-2030.

Skoe, E., & Kraus, N. (2010). Auditory brainstem responses to complex sounds: A tutorial. *Ear & Hearing, 31*(3), 302-324.

Stillman, R. D., Crow, G., & Moushegian, G. (1978). Components of the frequency-following potential in man. *Electroencephalography and Clinical Neurophysiology, 44*, 438-446.

Terhardt, E., Stoll, G., & Seewann, M. (1982). Pitch of complex signals according to virtual-pitch theory: Tests, examples, and predictions. *Journal of the Acoustical Society of America, 71,* 671–678.

TRANSFORMATION OF VOICE ONSET TIME IN HEARING AID PROCESSED SPEECH AND ITS RELATION WITH NUMBER OF CHANNELS IN HEARING AIDS

[1]Ajish K. Abraham

Abstract

Modification of temporal features of a speech signal as it passes through the processing stages in a digital hearing aid may affect the speech recognition and speech perception. Transformation of voice onset time (VOT) may be one factor which affects the intelligibility of hearing aid processed speech and thereby affecting the factor of clarity of sound. The contribution of VOT transformation in the degradation in speech quality with increase in the number of channels of a hearing aid needs to be investigated. The objectives of the study are 1) to acoustically analyze and extract VOT from the speech signal at the input and output of a 2, 4, 6 and 16 channel digital hearing aid, 2) to estimate the transformation of VOT in a 2, 4, 6 and 16 channel hearing aid processed speech and 3) to investigate the effect of number of channels of hearing aids on this transformation. The stimulus consisted of three meaningful voices cognate word pairs, such as BEES / PEAS, DIME / TIME and GOAT / COAT produced by a male adult (native Kannada) speaker. VOT values were found out for the UN processed stimuli and for the processed stimuli from four behind the Ear hearing aids, by using speech analysis software and then the corresponding changes in VOT was noted. Perceptual evaluation was done by six judges with normal hearing. Results showed a reduction in lead VOT by 16% in hearing aid processed speech which would result in degradation of speech intelligibility by about 11% and a reduction in lag VOT by 18.4% leading to a decrease in percentage intelligibility by 19.4%. No significant difference between the percentage reduction in lag VOT and lead VOT was observed across processed speech of hearing aids with different channels.

Keywords: *Voice Onset Time, lag VOT, and lead VOT, Percentage intelligibility, Just Noticeable Difference*

Hearing aids, the auditory rehabilitation aid used by majority of the people with hearing impairment, have undergone a technological transformation since the mid – 1990s. Followed by the emergence of the first digital hearing aid in the late 1990s, the pace of technology developments got faster and led to many innovations. Thus the present day hearing aids have become complex digital signal processors, with a wide range of programmable and adaptive features.

A survey (Kochkin, 2005) of more than1, 500 users of hearing instruments measured only 71% overall satisfaction with instruments that are 0 – 5 years old, and 78% with 1 year old instruments. Some of the factors that relate most with customer satisfaction in this survey were clarity of sound (p=0.72) and natural sounding (p=0.68), where 'p' denotes correlation with overall hearing instrument satisfaction. These two factors which are ranked as 2nd and 5th respectively can be attributed to speech discrimination and percentage intelligibility. Nataraja, Savithri, Sreedevi and Sangeetha, (2000) estimated the changes in speech intelligibility as a result of modifying the temporal, spectral and prosodic parameters in the speech of the children with hearing impairment. Results indicated that modification of duration of the temporal parameters resulted in maximum improvement in intelligibility. Hence, modification of duration of temporal parameters of a speech signal as it passes through the processing stages in a digital hearing aid may affect the speech recognition and speech perception and this requires to be investigated.

Momentary blockage of the vocal tract due to an articulatory occlusion is a characteristic of stop consonants /p b t d k g/. Duration of the blockage usually varies between 50 to 100 ms. The blockage is then released with a burst of air. After the burst and a brief interval, next is the onset of vocal fold vibrations (voicing) for the vowel which follows. Voice onset time (VOT) is specified as the time interval between two events that is, between the release of a complete articulatory occlusion and the onset of quasi-periodical vocal fold vibration.

VOT is a relevant perceptual cue to distinguish between voiced and voiceless and between aspirated and unaspirated stops. VOT measures are commonly used in research and clinical

[1]Reader in Electronics & Acoustics, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: ajish68@aiishmysore.in

practice, and have been used in the developmental maturation of neuromotor coordination, (DiSimoni, 1974) speech production of hearing-impaired talkers (Monsen, 1976) and assessment and treatment of individuals who stutter (Borden, Baer & Kenney, 1985). VOT is considered a major cue for differentiation of prevocalic stops along the voicing dimension (Lisker and Abramson, 1964, 1971, Abramson and Lisker, 1965).

Eguchi & Hirsh (1969) and Kent (1976) have opined that the distinctive acoustic cue VOT is helpful to assess the general process of motor skill acquisition. Research of speech development in children has given due importance to VOT as an important temporal feature. Zlatin (1974) reported that VOT is a primary cue for differentiation of homorganic stop consonants. Hansen, Gray and Kim (2010) reported that, the important temporal feature VOT is often overlooked in perception as well as recognition of speech.

The study conducted by Nataraja et al., (2000) considered altering the duration of the temporal parameters in the speech of the children with hearing impairment and evaluated the improvement in intelligibility. In single cue condition, in the initial position, burst duration and VOT were transformed; in the medial position, consonant duration, closure duration, and transition duration of the second formant and preceding and following durations were transformed. Results show that among all temporal parameters whose transformation resulted in improvement of intelligibility and percentage discrimination of the speech of children with hearing impairment, VOT was the one with maximum effect. Hence, alteration of VOT may be one factor which affects the intelligibility of hearing aid processed speech and thereby affecting the factor of clarity of sound. Hence, it needs to be investigated whether VOT is getting affected when the speech signal undergo signal processing in hearing aids.

Keidser and Grant (2001) reported no significant difference in speech recognition in one, two or four channel hearing aids. Abhaykumar (2010) compared the speech identification scores with single channel, multichannel and channel free hearing aids in quiet condition. Results indicated that there is no statistically significant difference between the scores. Volker Honmann and Birger Kollmeir (1995) conducted an experiment using an algorithm for amplification with 23 independently compressed frequency channels to find out the effect of multichannel dynamic compression on speech intelligibility. They observed distinct degradation in speech quality and virtually no decrease in speech intelligibility for high signal to noise ratios when tested with normal hearing listeners. Proportional change in VOT with increase in the number of channels of a hearing aid transformation may contribute degradation in speech quality which needs to be investigated.

It is essentially required to increase the overall satisfaction of users of hearing instruments from the measured level of 71 to 78% (Kochkin, 2005). This would be possible, if the factors that relate most with customer satisfaction namely, clarity of sound and natural sounding are enhanced. This study would help to find out whether there are any changes in VOT in a hearing aid processed speech and if so whether these changes have got any impact on these factors with specific reference to increase in the number of channels. Results of this study would provide technical inputs to the designers of signal processing algorithm to make the required changes in the software design of hearing aids to enhance the clarity of sound and natural sounding in the processed speech at the hearing aid output.

The objectives of the study were 1) to acoustically analyze and extract VOT from the speech signal at the input and output of a 2, 4, 6 and 16 channel digital hearing aid, 2) to estimate the transformation of VOT in a 2, 4, 6 and 16 channel hearing aid processed speech and 3) to investigate the effect of number of channels of hearing aids on this transformation.

Method

Stimuli: Three meaningful voice cognate word pairs, such as BEES / PEAS, DIME / TIME and GOAT / COAT were selected for study. This corresponds to the same series of stimuli developed by Lisker and Abramson (1967) for similar studies. The stimuli comprises six plosives in the initial position categorized as unvoiced (velar /k/, dental /t/, and bilabial /p/) and voiced (velar /g/, dental /d/ and bilabial /b/).

Recording: Each of the word in the stimulus list was uttered by an adult (native Kannada) male speaker and was recorded by a condenser microphone (B & K 4189) that was placed at a distance of 15 cm from the mouth of the speaker. The syllables were recorded by the precision sound level meter (B & K 2250) with sound recording software (B & K BZ7226). The recorded samples were digitized at a sampling frequency of 22 kHz and 16 bits / sample and were stored on a PC.

Instrumentation: The signals required for measurement of VOT as well as for analysis are acquired and processed by the set up shown in figure 1. To deliver the recorded stimuli, the corresponding wave file is downloaded to the front end of the analyzer (B & K Pulse 12.0) system. The stimulus is delivered through a leveled response loudspeaker to the hearing aid under test kept in the anechoic test chamber (B & K4232). To rule out any distortion in the delivery path, a dedicated hardware unit (B & K Pulse 12.0) and a power amplifier (B & K 2716C) were included in the stimulus delivery path. Four behind the ear digital hearing aids were used for testing. These hearing aids differed in terms of the number of channels, two, four, six and sixteen, but incorporated similar signal processing strategy. They incorporated wide dynamic range compression. The hearing aids under test were programmed with the first fit algorithm. The stimuli after being processed from all 4 hearing aids were collected by B & K 4189 condenser microphone that is placed inside a 2cc coupler and were recorded by BZ 7226 recording setup. Recorded processed syllables were stored on the PC for further analysis.

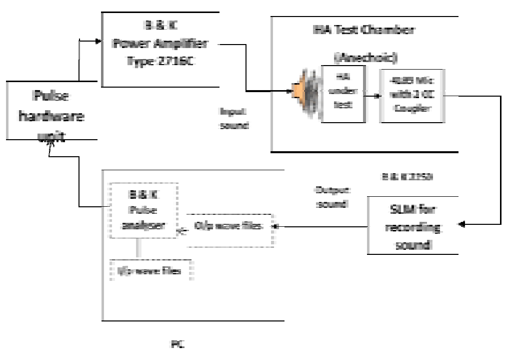

Figure 1: *Instrumentation for signal acquisition, measurement and analyses*

Test environment: Measurement as well as stimulus (both processed and unprocessed) recording was carried out in a sound proof room built as per ANSI S3.1 - 1991 standards.

Subjects: Six post graduate students of AIISH, Mysore with normal hearing, participated as judges in the study. The judge did not know in advance, the word pair presented for judgment. Participants were asked to assess whether two sounds were the same or different in a fixed AX discrimination task. For each input output stimulus pair, a score of 1 was given for “different” and 0 for “same”. Maximum score for this test was 'four' for each category of stimuli because four numbers of hearing aids were included in the study.

Procedure: Hearing aid processed speech from all four hearing aids with six input stimuli to each of them were recorded. The input along with its output recordings were played back to six judges in random order. The judges were asked to perceive whether there is any difference between the input and output sample.

Acoustic Analyses: B & K Pulse Time Edit & Analysis software was used to measure the VOT values from the waveform of the processed / unprocessed stimuli. The interval between the release of stop occlusion and the onset of the following vowel was considered as VOT (Figure 2). The use of a waveform in the measurement of VOT values was found to be more accurate and reliable (Francis & Ciocca, 2003). Time measurement was directly done by the Time Edit and analysis software (B & K). In cases of difficulty in locating the points of measurement on a time scale, spectral analysis was employed (B & K Pulse 12.0).

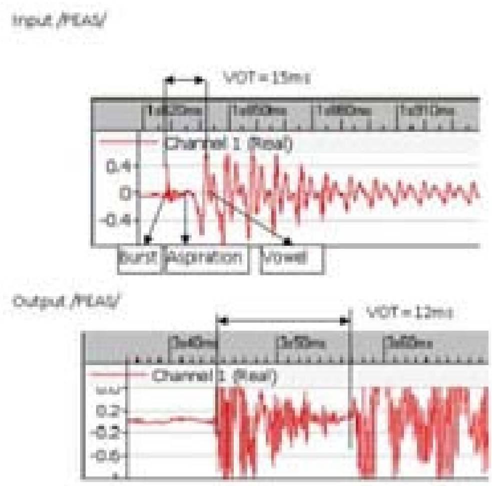

Figure 2: *Illustration of measurement of VOT*

Statistical analysis: SPSS (Version 18) software was used to carry out the statistical analysis. Friedman test was administered to find the effect of number of channels on transformation of VOT.

Reliability measurements: Reliability between judges who served as subjects for the study was tested using reliability coefficient Cronbach’s alpha and it showed sufficient reliability between judges (0.97).

Results and Discussion

Transformation in Lead VOT: Table 1 shows a reduction in lead VOT for all categories of hearing aids. Table 3 shows that percentage reduction in lead VOT was in the range of 14 to

20 with a mean of 17.67 in 2 channel hearing aid. In 4 channel hearing aid, the range was between 13 and 18 with a mean of 14.67. The range was from 13 to 16 with a mean of 15.67 in six channel hearing aid and was from 13 to 20 with a mean of 15.67 in sixteen channel hearing aid. Nataraja et al., (2000) reported that lead VOT in the speech of normal hearing group was significantly longer than that in hearing impaired children. They also reported that % improvement in speech intelligibility on enhancing the lead of VOT by 50% on an average in the speech of hearing impaired children was 33%. Considering this, it can be inferred that a reduction in lead VOT by 16% (table 3) in hearing aid processed speech would result in degradation of speech intelligibility by about 11%.

Table 1: *Reduction in VOT (%) for voiced plosives in various places of articulation*

Stimuli	2 channel hearing aid		4 channel hearing aid		6 channel hearing aid		16 channel hearing aid	
	Change in VOT (ms)	% change	Change in VOT (ms)	% change	Change in VOT (ms)	% change	Change in VOT (ms)	% change
Velar	15	20	10	13	12	16	15	20
Dental	15	14	20	18	20	18	15	14
Bilabial	15	19	10	13	10	13	10	13

Table 2: *Reduction in VOT (%) for un-voiced plosives in various places of articulation*

Stimuli	2 channel hearing aid		4 channel hearing aid		6 channel hearing aid		16 channel hearing aid	
	Change in VOT (ms)	% change	Change in VOT (ms)	% change	Change in VOT (ms)	% change	Change in VOT (ms)	% change
Velar	2	7	4	13	4	13	3	10
Dental	3	23	3	23	3	23	3	23
Bilabial	4	27	5	33	3	20	4	27

Transformation in lag VOT: Table 2 shows a reduction in lag VOT for all categories of hearing aids. Table 4 shows that percentage reduction in lag VOT was in the range of 14 to 20 with a mean of 17.67 in 2 channel hearing aid. In 4 channel hearing aid, the range was between 13 and 18 with a mean of 14.67. The range was from 13 to 16 with a mean of 15.67 in six channel hearing aid and was from 13 to 20 with a mean of 15.67 in sixteen channel hearing aid. Along the same lines on the discussion done in the case of lead VOT, Nataraja et al., (2000) reported that lag VOT in the speech of normal hearing group was significantly longer when compared with that in hearing impaired children. Percentage improvement in speech intelligibility is reported to be 45% when the lag VOT was enhanced by 43%. Referring to table 4, mean % reduction in lag VOT for all hearing aids put together is 18.4%. This may lead to a decrease in percentage intelligibility by 19.4% as per the figures arrived at by Nataraja et al., (2000).

Effect of number of channels on transformation in VOT: Table 3 & 4 shows the variation of percentage reduction in VOT across 2 channel, 4 channel, 6 channel and 16 channel hearing aids. Friedman test was administered to ascertain the significance of this. Results reveal that there is no significant difference between the percentage reduction in lag VOT and lead VOT across processed speech of hearing aids with different channels. (χ^2 (3) = 0.913, p>0.05 for lead VOT and χ^2 (3) = 3, p>0.05 for lag VOT). These results are in accordance with the findings of previous studies conducted by Keidser et al., (2001), Abhaykumar (2010) and Volker et al., (1995). These studies reported that speech intelligibility has no relation with the number of channels of hearing aids for inputs with high signal to noise ratio. Present study indicates that there is no effect of number of channels on VOT transformation and hence on speech intelligibility.

Table 3: *Mean, SD and Range of percentage reduction in lead VOT*

	2 channel hearing aid	4 channel hearing aid	6 channel hearing aid	16 channel hearing aid
Mean	17.67	14.67	15.67	15.67
SD	3.21	2.89	2.52	3.79
Range	5	6	5	7

Table 4: *Mean SD and Range of percentage reduction in lag VOT.*

	2 channel hearing aid	4 channel hearing aid	6 channel hearing aid	16 channel hearing aid
Mean	19	23	18.67	20
SD	10.58	10	5.13	8.88
Range	20	16	10	17

Perceptual evaluation: Table 5 shows the score of words perceived differently by judges when they were presented with 4 pairs of input output stimuli, each pair corresponding to input and output of one category of hearing aid. Reliability coefficient Cronbah's alpha showed sufficient reliability between judges (0.97).

Table 5: *Score of words perceived differently by judges* (V=voiced, U=unvoiced)

	Velar		Dental		Bilabial	
Judge	V	U	V	U	V	U
1	2	0	2	1	0	0
2	1	0	2	0	0	1
3	1	0	2	0	0	0
4	2	0	2	1	0	1
5	1	0	2	1	0	1
6	2	0	2	1	0	0
Mean score	1.5 (37.5 %)	0	2 (50 %)	0.66 (16.5 %)	0	0.5 (12.5 %)

The scores obtained by the judges are in accordance with the report of the study conducted by Ajith Kumar (2006). Ajith Kumar reported the values of VOT changes for each category of stop consonants to produce just noticeable difference (JND) for people with normal hearing. For unvoiced velar, the JND has a Mean of 27.9 ms and SD of 11.3 ms and this explains `0' score by the judges, as the change in VOT obtained in our study is in the range of 2 to 4 ms. In voiced velar, the JND has a mean of 32.1 ms and SD of 11.1 ms. As VOT transformation for voiced velar in our case ranges between 12 to 15 ms, the mean score is 37.5%.

In voiced dental, the JND has a mean of 35.1 ms & SD 9.9 ms, whereas our studies showed a range of 15 to 20 ms and hence the mean score is 50%. For unvoiced dental the JND has a mean of 15.5 ms with SD of 8 ms and this explains the score of only 16.5% as our results show 3 ms variation in VOT. For voiced bilabials the score is 0, as our result doesn't reach the vicinity of the JND (Mean 41.5 ms and SD 10.4 ms). Unvoiced bilabials had a VOT change of 3 to 5 ms whereas the JND has a mean of 13.7 ms with SD 5.5 ms and hence a score of 12.5%. Thus the scores obtained in perceptual evaluation tallies with the findings of objective analysis.

Conclusions

The present study measured VOT from the speech signal at the input and output of a 2, 4, 6 and 16 channel hearing aid and estimated the transformation of VOT in hearing aid processed speech. Results indicated a reduction in VOT which may lead to degradation in speech intelligibility which is supported by the results of perceptual evaluation by the judges. The study also investigated the effect of number of channels on the VOT transformation but could not find any significant relation. This indicates a need to investigate the transformation of other temporal parameters of the speech signal across the number of channels to explain the reported degradation of speech quality in proportion to the number of channels. The extent of degradation in VOT can be used as an indicator for hearing aid output quality. Results of this study indicate that, the signal processing algorithm in hearing aids needs to be modified to reduce the degradation in VOT. This step would result in enhancement of clarity of sound and natural sounding at the output of the hearing aid. Ultimately this would increase the overall satisfaction of users of hearing aids.

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References

Abramson, A.S. and Lisker, L. (1965). Voice onset Time in stop consonants: Acoustic Analysis and Synthesis. *5th International Congress of Acoustics, Liege, Belgium*.

Abhay Kumar, R (2010), Speech Identification with single channel, Multichannel and channels free hearing aids. *Student Research at AIISH Mysore,* V: 2006-07, 1-10.

Ajith Kumar U (2006). Perception of some temporal parameters of speech in individuals with auditory dys-synchrony. *Ph.D. Thesis, University of Mysore, Mysore.*

Borden, G.J., Baer, T, Kenney, M.K. (1985), Onset of voicing in stuttered and fluent utterances. *Journal of Speech Hearing Research*, 28, 363-372.

Disimoni, F.G. (1974). Effect of vowel environment on the duration of consonants in the speech of three, six and nine year old children. *Journal of Acoustic Society of America*, 55, 360-361.

Eguchi, S and Hirsh, I.J. (1969). Development of Speech sounds in children. *Acta Otolaryngological supplement*, 257, 1-51.

Francis, A.L., Ciocca, V (2003). Accuracy and variability of acoustic measures of voicing onset. *Journal of Acoustic Society of America*, 113, 1025-1032.

Hanse John H.L., Gray, Sharmistha S., Kim, Wooil (2010). Automatic voice onset time detection for unvoiced stops (/p/, /t/, /k/) with application to accent classification. *Speech Communication*, 52, 777-789.

Kent, R.D. (1976). Anatomical and neuromuscular maturation of the speech mechanism: Evidence from acoustic studies. *Journal of speech and Hearing Research* 19, 421-447.

Keider, G and Grant, F (2001). The preferred number of channels (one, two or four) in NAL-NLI prescribed wide dynamic range compression (WDRC) devices. *Ear and Hearing*, 22(6), 516-527.

Kochkin, S. (2005). Customer satisfaction with hearing instruments in the digital age. *The Hearing Journal* 58 (9), 30-43.

Lisker, L, Abramson, A. (1964). A Cross-language study of voicing in initial stops: Acoustical measurements, *Word 20*, 384-422.

Lisker, L., & Abramson, A.S (1967). Some effects of context on voice onset time in English stops. *Language and Speech*, 10, 1-28.

Lisker, L, and Abramson, A. (1971). Distinctive features and laryngeal control. *Language*, 47, 767-785.

Monsen, R B. (1976). Normal and reduced phonological space: The production of vowels by a deaf adolescent. *Journal of Phonetics*, 4, 189-198.

Nataraja N.P., Savithri S.R, Sreedevi N, and Sangeetha, M. (2000). *Transformation of the speech of the Hearing Impaired,* Project at AIISH, Mysore funded by Department of Science and Technology, New Delhi.

Volker Hohmann and Birger Kollmier (1995). The effect of multichannel dynamic compression on speech intelligibility. *Journal of Acoustic Society of America*, 97, (2), 1191-1195.

Zlatin, M.A. (1974). Voicing contrast: Perceptual and productive voice onset time characteristics of adults. *Journal of Acoustic Society of America*, 56, 981-994.

CORRIGENDUM

The authors, Deepa, M. S. & Shyamala, K. C., are tendering an apology to the authors V. B. Fleming and J. L. Harris (2008). The apology reads as follows, “We deeply apologize to V.B. Fleming and J.L. Harris (2008), “Complex discourse production in mild cognitive impairment: Detecting subtle changes”, Aphasiology, Vol. 22, Issue 7-8 , pp 729-740, as well as the editor of the Journal of Aphasiology and regret the omission of their citation in abstract of page 12, paragraphs three of page 13 and 14, paragraph two of page 18, paragraphs two, three and four of page 19 in our article “Complex discourse production in persons with mild dementia: Measures of richness of Vocabulary”, Journal of All India Institute of Speech and Hearing, Vol. 29, No. 1, 2010, pp 12-22”.

In view of this the article titled “Complex discourse production in persons with mild dementia: Measures of richness of Vocabulary” authored by Deepa, M. S. & Shyamala, K. C. and appearing in the Journal of the All India Institute of Speech and Hearing, Vol. 29, No. 1, 2010, pp 12-22” is retracted.

Dr. S. R. Savithri
Editorial Chief