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VOICE ONSET TIME FOR VOICED STOP CONSONANTS IN TYPICAL MALAYALAM SPEAKERS.

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INTRODUCTION

Voice is the tone produced by the vibrating vocal folds (Aronson, 2009). The sound then is shaped by the vocal tract into a unique acoustic form that allows the listener to recognize the speaker. It is a combination and interaction of the mechanisms of respiration, phonation, resonance and articulation (Schneider, 2007).

Phonatory apparatus adjustment in shaping of the vocal tract, timing and coordination of articulation etc will add several physical features to the acoustic output. This can be extracted or measured by carrying out an acoustic analysis. An acoustic analysis is the measurement or graphing of acoustic information about the voice. This includes voice measures such as fundamental frequencies, formant pattern, energy decibel level, signal to noise ratio, jitter, shimmer, Voice Onset Time (VOT), Voice Reaction Time (VRT) etc.

Weismer & Hoit, (2009)

VOT is defined as the length of time that passes between the release of a stop consonant and the onset of voicing or the vibration of the vocal fold. VOT is an important acoustic feature and temporal cue for discriminating voiced and unvoiced phonemes and also a feature of the production of stop consonants in various languages. It reflects subtle motor coordination skills. Studies have been conducted on changes in several acoustic

parameters of voice with respect to age and gender about studies' concerning voice onset time and gender has been very less documented.

VOT can vary with the rate of speech, especially for voiceless aspirated (long-lag) stops. As would be expected, VOT decreases as rate of speech increases, and VOT increases as rate decreases (Baum & Ryan, 1993).

Age and gender has been reported to be closely related to the VOTs and gender difference is observed between the adults and adolescents. Stops require delicate temporal coordination between oral closure release and glottal vibration. Therefore during the early phase of motor speech development children require a much longer time to acquire the production of these sounds. However, no consistent conclusions have been drawn with regard to the age and gender difference in VOTs between adult and adolescents. Hence this study investigates the changes in VOT as a function of age and gender influence of place of articulation on VOT in a wide range of participants.

There are no consistent conclusions drawn with regard to the age difference and gender difference in VOTs between adolescents and adults. Indian investigators have reported that perception and production of voice onset time changes as a function of age in children. But little information is available concerning voice onset time changes with respect to age, gender and also place of articulation in South Indian contexts. Therefore, this investigation will examine changes in mean voice onset time and voice onset time variability with respect to place of articulation in 2 age groups and also gender differences.

REVIEW OF LITERATURE

Speech is a system of communication that uses sound symbols. In other words, speech is 'movements made audible'. It is a combination and interaction of the mechanisms of respiration, phonation, resonance and articulation (Schneider, 2007).

Voice, articulation and language are the major elements of human speech production. Voice is the element of speech that provides the speaker with the vibratory signal upon which, speech is carried. The study of voice production and its efficiency requires information on mechanics of vocal fold vibration and laryngeal muscles. The tension of the vocal folds rotates the cricoids and thyroid cartilage due to the contraction of crico-thyroid and thyro-arytenoid muscles, which are involved in the adduction and abduction of vocal folds.

Vocal fold length of boys and girls appear to be similar until about the age of ten years. After that point, there is gradual but consistent gender specific development that increases the overall length of vocal folds. By adulthood, the female vocal fold length ranges from 11 to 15mm whereas in males, it ranges from 17 to 21mm. Vocal fold will be elongated and the thickness will be reduced for high frequency, whereas for low frequency sounds the vocal fold length will be less and thickness is more (Stemple, Joseph, Roy).

Voice onset time (VOT) is measured as the time interval between the release burst and the first quasi periodicity in the acoustic signal (Lisker & Abramson, 1964; Klatt, 1975).

VOT in adults and adolescents are different. Vickie, Nil and Pang, the younger children produce longer VOT values with higher levels of variability. Also, higher VOT values and increased variability were found in the ages between 8 to 11 years.

Petrosino & Colcord (1993) documented increased VOT variability in older subject when compared to young adults. This apparent increase in variability may be related to the subtle anatomical and physiological changes with age.

Acoustic characteristics of stops include Closure Duration, Voice Onset Time (VOT), Release Burst and Formant Transition.

TYPES OF VOICE ONSET TIME (VOT).

1) Negative VOT: where the onset of vocal fold vibration precedes the plosive release. If the voicing starts before the release (i.e during the closure phase) of the stop, then the result is described as 'voice lead' (or 'prevoiced') and is given a negative VOT value. This is the case of voiced plosives.
2) Zero VOT: where the onset of vocal fold vibration coincides (approximately) with the plosive release. Voiceless un-aspirated plosives have zero voice-onset time.
3) Positive VOT: where there is a delay in the onset of vocal fold vibration after the plosive release. If the voicing starts after the release of the stop, then the result is 'voice lag' and is described with a positive VOT value. All voiceless aspirated plosives have positive value of voice-onset time. The amount of lag is important to separate voiceless un-aspirated ('short lag') from voiceless aspirated ('long lag').

Investigators have examined several acoustic and perceptual aspects of speech which are affected by age and gender related changes. These areas include pitch, intensity, quality and selected measurement of rate and duration. With respect to measurements of rate and duration, investigators have examined age-related changes in rate of speech, maximum vowel duration, pause time, and voice onset time.

Titze (1994) shows that the average vocal fold membrane length is 6mm shorter in female adults compared to male adults. The shorter membrane length in turn increases the possibility of a more rapid closure gesture, which is shown by the higher average f0 value in female speech compared to male speech. If VOT influenced by the abduction speed of the vocal fold (Port and Preston, 1974) then, male and female plosives would be unequally affected by this factor, creating a gender bias.

Using VOT measurements obtained from the waveform of productions made by adult male and female native speakers of American English, Swartz showed a significant difference in VOT due to gender and also this difference did not correlate with the higher speaking rate of men compared to women.

WESTERN STUDIES

Swartz (1992) conducted a study on gender difference in voice onset time. He investigated the significant gender difference in VOT production of the /d/ and /t/ stops, with men having shorter VOTs than women. Qualitative differences in VOT based on gender were also noted. Although a significant difference in speaking rate between the genders was found, this was not correlated with VOT.

Oh (2011) studied the effect of speaker's gender on voice onset time in Korean stop. This study reveals that in English language, females tend to exhibit larger VOT values that males for long-lag stops, but in Korean, males exhibited longer VOTs than females for aspirated stops.

Robb,Gilbert & Lerman (2005) investigated the influence of gender and environmental settings on voice onset time. This study suggested that VOT and CV duration for females produced voiceless stops with significantly longer VOT duration than male in both settings. Both gender groups produced CV tokens with significantly longer duration in the laboratory settings; however, females continued to produce CV token with longer duration in the non-laboratory setting.

Hoit, Solomon and Hixon (2005) investigated the Effect of Lung Volume on Voice Onset Time designed to test the hypothesis that voice onset time (VOT) varies as a function of lung volume. The finding points out the need to take lung volume into account when using VOT as an index of laryngeal behavior in both healthy individuals and those with speech disorders.

Neiman and Klich (1983) found out that VOT was generally the same in older and younger women, and both age groups maintained similar voiced/voiceless and bilabial/velar distinctions. Older women demonstrated significantly shorter VOTs only in certain contexts involving place of consonant production and vowel context.

Christopher, Crea, Herring (2007), studied the 'Voice onset time differences between adult males and females: Isolated syllables'. The purpose of the study was to compare the voice onset times (VOTs) produced by men and women in isolated syllable utterances. 40 male and 40 female speakers of English repeated a series of CV syllables five times each. The syllables were comprised of the plosives /p/,/t/,/k/,/b/,/d/,and /g/ in

combination with the vowels /ɑ/, /i/, and /u/. VOTs were measured from the middle three syllables from each series using a combination of sound spectrogram and oscillogram displays on a computer. No significant differences occurred between the VOTs of the male and female speakers. Significant VOT differences occurred across the vowels, with the plosives before /ɑ/ having shorter VOTs than those before /i/ or /u/. In addition, the VOTs varied by place of production, with longer VOTs for alveolar and velar plosives than for bilabial ones. The findings indicated that the speaker's gender was not a factor associated with VOT variability.

Stoltem, Abrashamsson & Hyltenstam (2014) investigated effects of age and speaking rate on voice onset time. The production of voiceless stops by near native 12 speakers and this study reports on voice onset time (VOT) analyses of the production of Swedish word-initial voiceless stops /p t k/. Voice onset time is analyzed in milliseconds as well as in percentages of word duration, thereby accounting for speaking rate effects. The results revealed an overall age effect on VOT production; however, this age effect became salient and statistically significant for all three stops only when speaking rate was taken into consideration. Similarly, when speaking rate was accounted for only a small minority of the late learners exhibited actual native like L2 behavior, and most (but far from all) early learners performed within native-speakers range. The results are taken as an indication for relative VOT, as opposed to absolute VOT, constituting liable measure of native like L2 stop production, which has important implications for future research on age effects and maturational constraints in L2 acquisition.

Brinca, Araujo & Nogueira (2016) studied the voice onset time characteristics of voiceless stops produced by children with European Portuguese as mother tongue. This study investigated the developmental pattern of VOT in pre-adolescent children and VOT characteristics of the voiceless stops consonants /p,t,k/ was studied. They found that VOT is not associated with gender, but decreases significantly with age. VOT value changed as a function of the place of articulation and the characteristics of the following vowel.

INDIAN STUDIES

Manjunath, Sneha & Narasimhan (2010) examined on variation in voice onset time in Kannada language. A total of 20 Kannada speaking young adults, of age ranging from 18 to 24 years participated in the study. A set of six meaningful phrases were constructed, which had voiceless and voiced sounds in initial position of the words. The result revealed that the VOT values were higher at slower rates and lower at faster speaking rates.

Kaur (2015) studied on the factors influencing voice onset time to evaluate the features which might estimate the closeness of acoustic signals. For measuring voice onset time, they considered 3 stop consonants in words-initial position and two abutted vowels /a/ and /i/. These 3 stop consonants were divided into voiced /b/,/d/,/g/ and voiceless /p/,/t/,/k/ categories. It has been found that voice onset time for voiceless consonants is larger than the voiced consonants. Further, VOT gets changed with effect of place on articulation. It has been found that velar has largest VOT following in descending order by alveolar labial. In addition to it, effect of vowel height on VOT was studied, which revealed that high vowel /i/ have larger voice-onset time than low vowel /a/.

Kumaraswamy and John (2018) Studied on effect of age and place of articulation on voice onset time. A total of 30 subjects were grouped into 3 age groups i. e. Group 1 (10-20) years, Group 2(40-50) years, and group 3 (60-70)years. The three voiced stop consonants /b/,/d/,/g/ were stimulus for this study. The result indicates that age and place of articulation is a factor associated with VOT in typical Malayalam speakers. The place of articulation and VOT were related and generally longer for /g/ than for /d/ and /b/.

Need of the study

There are no consistent conclusions drawn with regard to the age difference and gender difference in VOTs between adolescents and adults. Indian investigators have reported that perception and production of voice onset time changes as a function of age in children. But little information is available concerning voice onset time changes with respect to age, gender and also place of articulation in South Indian contexts. Therefore, this investigation will examine changes in mean voice onset time and voice onset time variability with respect to place of articulation in 2 age groups and also gender differences.

Aim

The aim of the present study was to investigate the influence of gender and place of articulation on voice onset time among adolescents and adult in typical Malayalam speakers.

METHOD

The aim of this study was to investigate the effects of age and gender on voice onset time with respect to voiced stop consonants in typical Malayalam speakers.

Subject

Group of 80 members who were further divided into 40 adolescents (group1) and 40 adult (group 2).

Inclusion criteria

- No history of neurological, vascular and motor abnormalities
- Should be a native Malayalam speaker
- Age selected is to be specific for the testing

Exclusion criteria

- Geriatric populations
- Non- native Malayalam speakers

Stimulus preparation

Three voiced stop consonants/b/,/d/,/g/ were selected with each occurring in the initial position of the word. The stimulus words used were /bʌlam/,/dʌppa/,/gʌŋa/.

Procedure

Participants were clearly instructed about the procedure and the recordings were carried out in a well illuminated room. The participants were seated comfortably in front of a computer connected to a microphone kept at a constant distance of approximately 5cm from the mouth of the speaker. Each target stimulus was written orthographically in Malayalam characters on a piece of paper. Participants were first asked to practice how to read the target words isolation and the tester would help to correct their mispronunciations so to make it clear that how to articulate the target words correctly. During the formal recording, they were required to read the words in a normal speed. All productions were recorded with a sampling rate of 44.1 kHz.

Measurement

The recorded samples were analyzed using PRAAT software version (5.2.25 by Boersma and Weenink in 2011) and the obtained data was further statistically analyzed with ANOVA test and post hoc test for significant difference.

RESULT

The present study aimed to assess the Effect of VOT across Genders with respect to Age and Place of Articulators in different age group (adolescents and adult).the obtained data was statistically analyzed and the results are given below.

1. Voice onset time in different age group:

Table: 4.1 Showing the mean and standard deviation of voice onset time for bilabial /b/ in different age group.

Group	N	Mean	Std. Deviation	95% confidence interval for mean		t. test p value
				Lower bounder	Upper bounder	
Adolescents	40	21.25	4.247	19.89	22.61	.000
Adult	40	26.15	5.447	24.41	27.89	HS

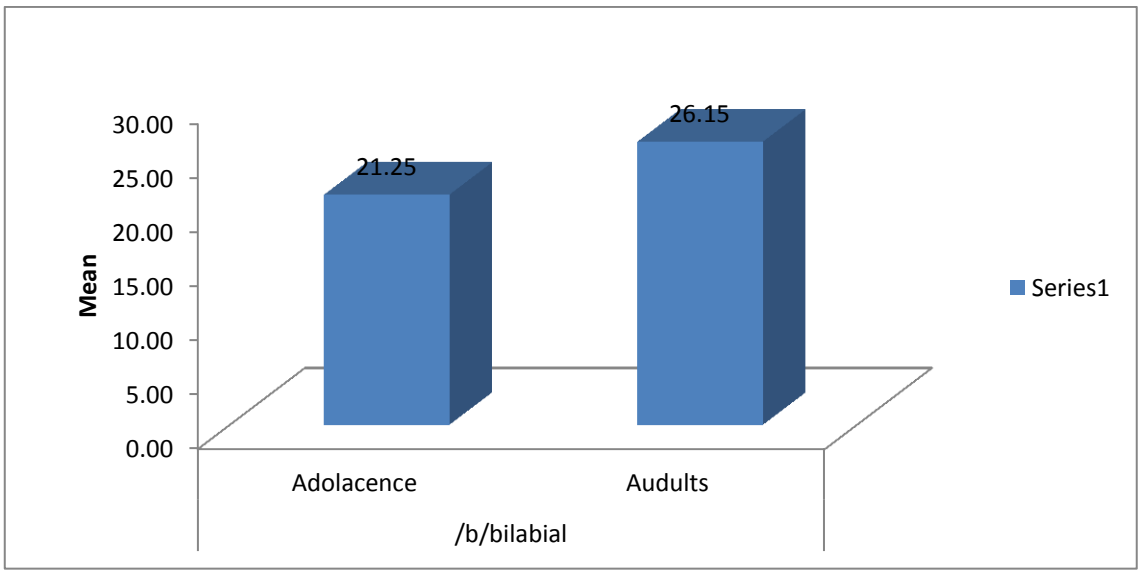

Figure: 4.1 Showing the mean value of voice onset time for bilabial/b/ in Adolescents and Adult.

From the above figure and the table4.1, it can be seen that mean VOT for adolescents and adult for bilabial /b/ was 21.25 and 26.15. When statistical comparison of adolescents and adults were done, it yielded highly significant results (p value; .000).

Group	N	Mean	Std. Deviation	95% confidence interval for mean		t. test p value
				Lower bounder	Upper bounder	
Adolescents	40	23.53	4.397	22.12	24.93	.000 HS
Adult	40	27.63	4.705	26.12	29.13	

Table: 4.2 Showing the mean and standard deviation of voice onset time for alveolar /d/ in different age group.

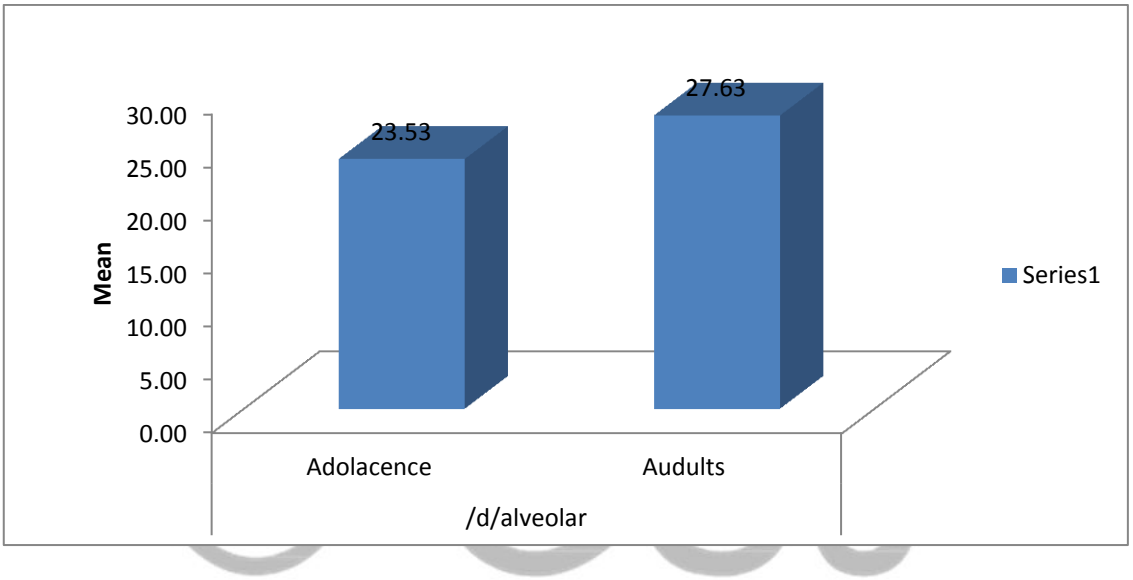

Figure: 4.2 Showing the mean value of voice onset time for alveolar/d/ in Adolescents and Adult.

From the above figure and the table 4.2, it can be seen that mean VOT for adolescents and adult for alveolar /d/ was 23.53 and 27.63. When statistical comparison of adolescents and adults were done, it yielded highly significant results (p value; .000) .

Group	N	Mean	Std.Deviation	95% confidence interval for mean		t.test p value
				Lower bounder	Upper bounder	
Adolescents	40	26.35	4.715	24.84	27.86	.001 HS
Adult	40	30.90	6.686	28.76	33.04	

Table: 4.3 Showing the mean and standard deviation of voice onset time for velar/g/ in different age group.

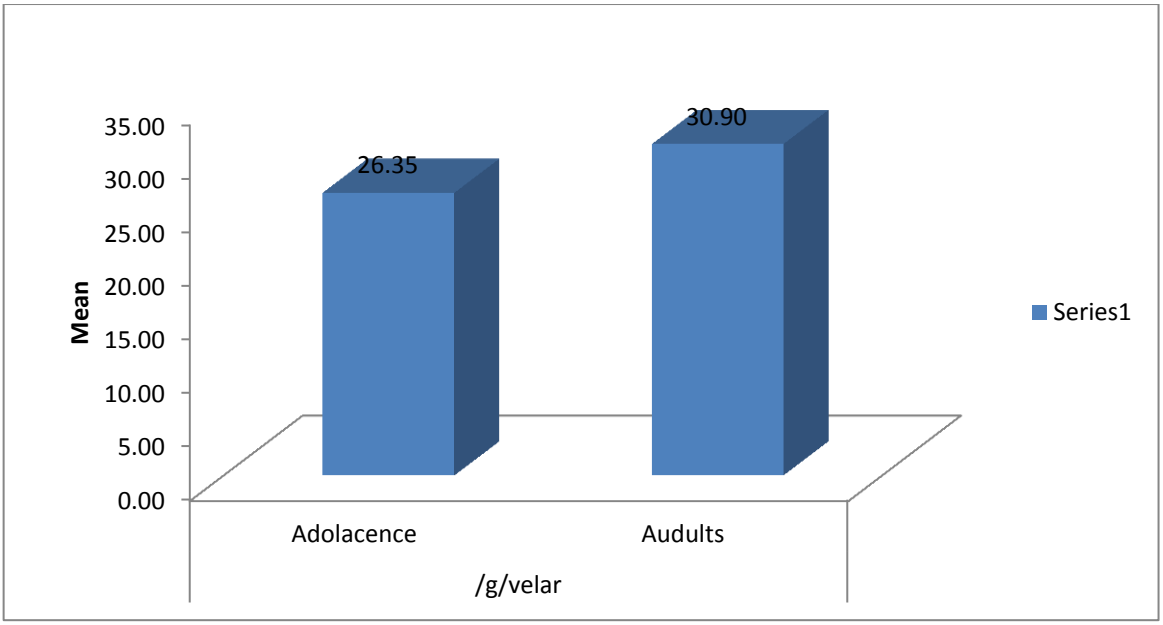

Figure: 4.3 Showing the mean value of voice onset time for velar/g/ in Adolescents and Adult.

From the above figure and the table 4.3, it can be seen that mean VOT for adolescents and adult for velar /g/ was 26.35 and 30.90. When statistical comparison of adolescents and adults were done, it yielded highly significant results (p value; .001).

2. Voice onset time across genders.

Group	gender	mean	Std.Deviation	95% confidence interval for mean		t.test p value	
				Lower bounder	Upper bounder		
Adolescence	Female	21.65	5.254	19.19	24.11	.558	NS
	Male	20.85	3.014	19.44	22.26		
Adult	Female	28.05	5.889	25.29	30.81	.025	Significant
	Male	24.25	4.315	22.23	26.27		

Table: 4.4 Showing the mean and standard deviation of voice onset time across genders for bilabial/b/ in different age group.

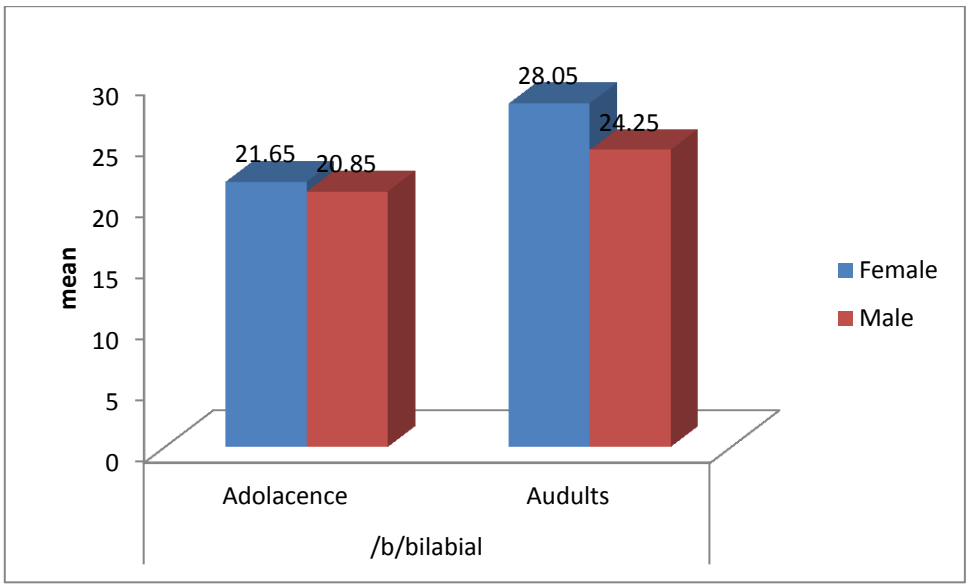

Figure: 4.4 Showing the mean value of voice onset time across genders for bilabial/b/ in Adolescents and Adults.

From the above figure and the table 4.4, it can be seen that mean VOT value for adolescents across the group of females and males for bilabial /b/ was 21.65 and 20.85 and statistical comparison yielded no significant results (p value; .558).

The mean VOT value for Adult across the group of females and males for bilabial /b/ was 28.05 and 24.25 and statistical comparison yielded significant results (p value; .025).

group	gender	mean	Std.Deviation	95% confidence interval for mean		t.test p value	
				Lower bounder	Upper bounder		
Adolescence	Female	25.15	4.075	22.95	27.35	.017	Significant
	Male	21.90	3.463	20.28	23.52		
Adult	Female	29.70	4.996	27.36	32.04	.004	HS
	Male	25.55	3.379	23.97	27.13		

Table: 4.5 Showing the mean and standard deviation of voice onset time across genders for alveolar/d/ in different age group.

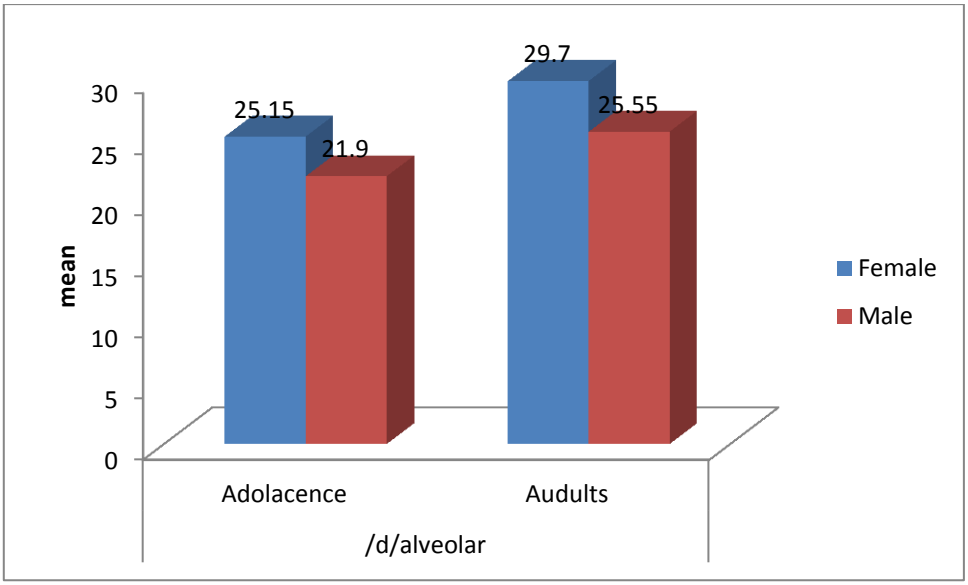

Figure: 4.5 Showing the mean value of voice onset time across genders for alveolar/d/ in Adolescents and Adults.

From the above figure and the table 4.5, it can be seen that mean VOT value for Adolescents across the group of females and males for alveolar /d/ was 25.15 and 21.9 and statistical comparison yielded highly significant results (p value; .017).

The mean VOT value for adult across the group of females and males for alveolar /d/ was 29.7 and 25.55 and statistical comparison yielded highly significant results (p value; .004).

Group	gender	mean	Std.Deviation	95% confidence interval for mean		P value	
				Lower bounder	Upper bounder		
Adolescence	Female	26.60	4.535	24.48	28.72	.742	NS
	Male	26.10	4.994	23.76	28.44		
Adult	Female	34.30	6.705	31.16	37.44	.001	HS
	Male	27.50	4.741	25.28	29.72		

Table: 4.6 Showing the mean and standard deviation of voice onset time across genders for velar/g/ in different age group.

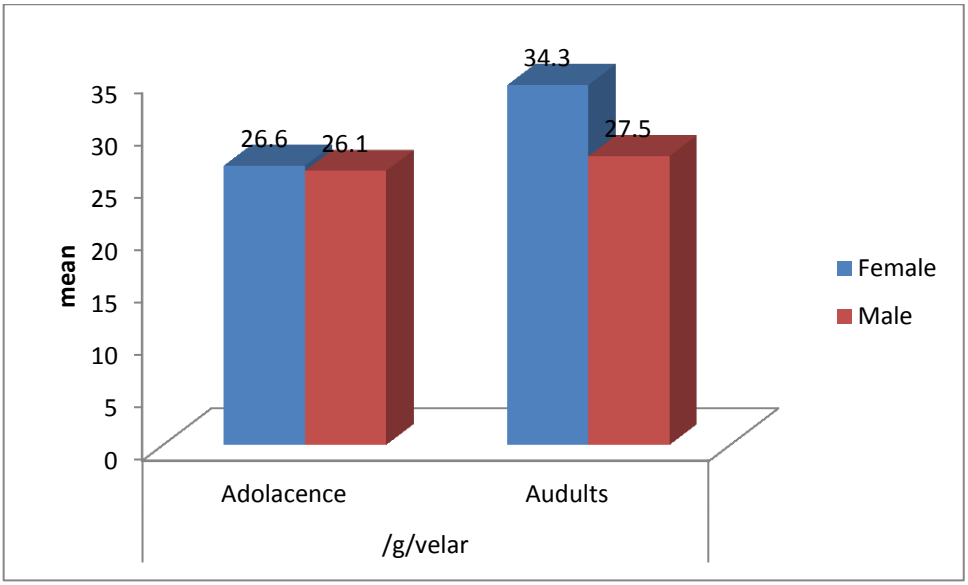

Figure: 4.6 Showing the mean value of voice onset time across genders for velar/g/ in Adolescents and Adults.

From the above figure and the table 4.6, it can be seen that mean VOT value for adolescents across the group of females and males for velar /g/ was 26.00 and 26.1 and statistical comparison yielded no significant results (p value; .742).

The mean VOT value for adult across the group of females and males for velar/g/ was 34.3 and 27.50. When statistical comparison of adolescents and adults were done, it yielded highly significant results (p value; .001).

DISCUSSION

From the above result it can be seen that mean value for VOT in adolescence and adult for bilabial /b/ was 21.25 sec and 6.15 sec when statistically compared it was highly significant for /b/ and /p/ across adolescence and adult whereas alveolar /d/ had a mean VOT of 23.53 sec and 27.63 sec which shows that adults perform better and statistically highly significant (p=0.000) was obtained and velar /g/ showed mean value of 26.35 sec and 30.90 sec, again confirming adult performance was slightly better when compared to adolescence and statistically highly significant difference (p=0.001) was seen.

The present study is in accordance with Sweeting and Baken (1982) where they say fine motor coordination is required to maintain the articulatory and laryngeal adjustments represented by measures of VOT will change as a function or normal aging. Also correlated with Stoltem, Abrahamson & Hyltenstam (2014) where they have reported the effects of age and speaking rate on voice onset time. The production of voiceless stops by near native 12 speakers and this study reports on voice onset time (VOT) analyses of the production of Swedish word-initial voiceless stops /p/, /t/, /k/. Voice onset time is analyzed in milliseconds as well as in percentages of word duration thereby accounting for speaking rate effects. The results revealed an overall age effect on VOT production; however, this age effect became salient and statistically significant for all three stops only when the speaking rate was taken into consideration. Similarly, when speaking rate was accounted for only a small minority of late learners exhibited actual native like L2 behavior and most(but far from all) early learners performed within native speakers range. The results are taken as an indication for relative VOT, as opposed to absolute VOT constituting liable measure of native like L2 stop production, which has important implications for future research on age effects and maturational constraints in L2 acquisition.

No significant results (p=0.558) for bilabial /b/ was obtained when data was across compared with gender, whereas alveolar /d/ showed significant (p=0.17) in adolescence and highly significant (p=0.004) for adults followed by significant difference (p=0.17) for adolescence and high significant difference for adults in velar /g/.

The present study is in accordance with Oh (2011) where he reports that females tend to exhibit larger VOT than males for long lag stops but Korean males exhibited longer VOTs than females for aspirated sounds and also correlated with Robb, Gilbert & Lerman (2005) reported that the influence of gender and environmental settings on voice onset time. The present study suggested that VOT and CV duration for females producing voiceless stops was significantly longer VOT duration than male in both settings. Both gender groups produced CV tokens with significantly longer duration in the laboratory settings; however females continued to produce CV token with longer duration in the non-laboratory settings also.

SUMMARY AND CONCLUSION

Voice onset time is measured as the time interval between the release burst and the first quasi periodicity in the acoustic signal (Lisker and Abramson 1964). VOT value are not absolute; they are rather influenced by several factors such as rate of speech, gender, age, vowel duration, height of the vowel, place of the articulation and so on.

The aim of this study was to investigate the effects of age and gender on voice onset time with respect to voiced stop consonants in typical Malayalam speakers.

For this study 80 subjects were grouped into two age group (adolescence and adult). The three voiced stop consonants /b/, /d/, /g/ were stimulus for the study. The participants were seated comfortably in front of a computer connected to a microphone kept at a constant distance of approximately 5cm from the mouth of the speaker. The utterances were recorded and acoustically analyzed via PRAAT. During the formal recording, they were required to read the words in a normal speed. All productions were recorded with a sampling rate of 44.1 kHz. The VOT values of the target stops were obtained from the wave form and verified with the spectrogram. As for the spectrographic readings VOT intervals from the beginning of the release burst to the onset of voicing were analyzed. The obtained data statistically analyzed.

The result conforming that adult performance was slightly better when compare to adolescence for all the voiced stop consonants/b/, /d/, /g/. Across genders females are having high VOT when compare to males,

The mean VOT value for adolescents across the group of females and males for bilabial /b/ was 21.65 and 20.85 and statistical comparison yielded no significant results (p value; .558) and for Adult across the group of females and males for bilabial /b/ was 28.05 and 24.25 and statistical comparison yielded significant results (p value; .025)

The VOT value for Adolescents across the group of females and males for alveolar /d/ was 25.15 and 21.9 and statistical comparison yielded highly significant results (p value; .017) and for adult across the group of females and males for alveolar /d/ was 29.7 and 25.55 and statistical comparison yielded highly significant results (p value; .004)

The mean VOT value for adolescents across the group of females and males for velar /g/ was 26.00 and 26.1 and statistical comparison yielded no significant results (p value; .742) and for adult across the group of females and males for velar/g/ was 34.3 and 27.50. When statistical comparison of adolescents and adults were done, it yielded highly significant results (p value; .001).

In summary we can conclude that there is significant difference in VOT across genders as well as age. So these findings can be later used in the assessment and diagnosis procedures. Moreover these finding can be later used as reference for further studied to be done in different populations as well as other age groups.

The present study is in accordance with Oh (2011) where he reports that females tend to exhibit larger VOT than males for long lag stops but Korean males exhibited longer VOTs than females for aspirated sounds.

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