DURATION OF VOWELS IN ORIYA: A DEVELOPMENTAL PERSPECTIVE

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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

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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 (years; months)	N	females/ males	Age 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.

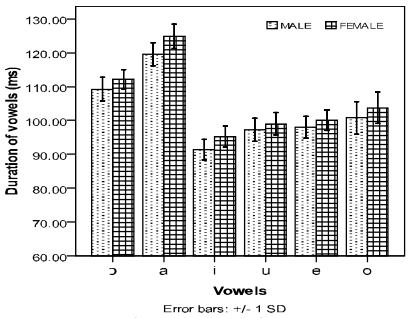

Figure: 1. *Mean of durations of vowels in the post vocalic voiced consonant context produced by male and female speakers in the adult group.*

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.

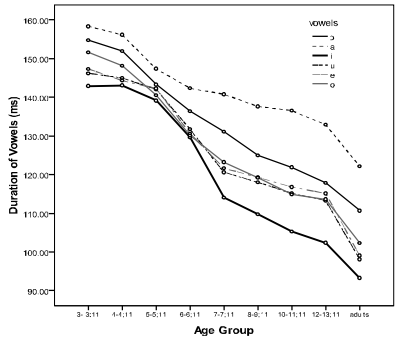

Figure 2: *Mean values of duration of all six vowels in the post vocalic voiced stop consonant context produced by participants in the nine age groups*

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.

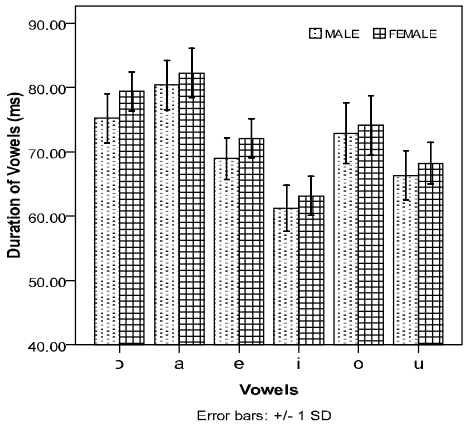

Figure 3: *Mean of durations of vowels in the post vocalic unvoiced consonant context produced by male and female speakers in the adult group.*

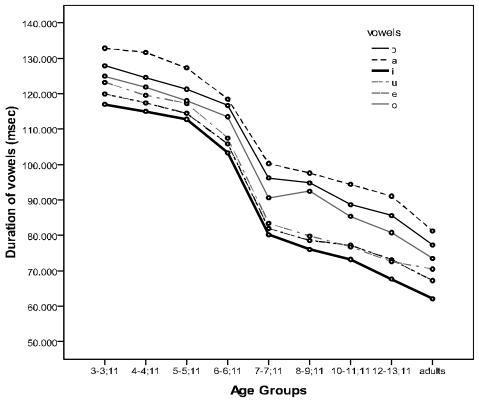

Figure 4: *Mean values of duration of all six vowels in the post vocalic unvoiced stop consonant context produced by participants in the nine age groups.*

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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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/, /ɔḍa/, /ɔɽa/	/ɔpa/, /ɔʈa/, /ɔt̪i/
/a/	/aḍi/, /abe/, /age/	/ape/, /aʈɔ/
/i/	/iɽa/	/iʈa/, /it̪i/
/u/	/uɽa/, /uḍa/, /uga/	/uka/, /upi/
/e/	/ebe/,	/eka/, /eʈe/
/o/	/oḍa/	/oʈɔ/