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Acquisition of Hindi Peripheral Vs. Central Vowels

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Abstract

This paper focuses on the acquisition of peripheral and central vowel space in Hindi speaking children aged 2 to 5 years. The study assumes that the acoustic space is continuously being redefined and modified in order to achieve and maintain a certain perceptual contrast, and attempts to explore how acoustic space develops in children in the first few years of language development.

The study presents a graphic representation of the acoustic space of three peripheral and three central vowels of Hindi. This study uses the first two formants of the vowels along with duration. The development of acoustic space in

twenty-two Hindi speaking children from 2 to 5 years of age shows significant results which are presented in this paper.

Keywords: Acoustic Space, Child Language Development, Peripheral Vowels, Central Vowels, Duration, Formants.

1. Introduction

Acoustic studies on Hindi vowel system with special reference to the vowel spaces have shown that the two vowel spaces namely peripheral and central are important. These vowels in contrast are perceived to be placed in the vowels space with the three central vowels generally shorter in duration in comparison with their corresponding peripheral vowels.

Hindi native speaker understand /I/ - /i/ distinction as short /I/ and long /i/. Similarly, /U/ - /u/ as short /U/ and long /u/. The difference between /I/ - /i/ and /U/ - /u/ is perceived as durational difference whereas in case of /ə/ - /a/ the difference between the two is perceived as that of quality. But empirical studies show that both the differences in quality and quantity exist between all the three pairs of vowels.

. Vowels	Hindi word	Transcription	Gloss
/i/	पपीता	/pəpita/	*Papaya*
/a/	किताब	/kItab/	*Book*
/u/	जूता	/juta/	*Shoe*
/I/	किताब	/kItab/	*Book*
/ ə/	बकरी	/bəkri/	*Goat*
/U/	कुता	/kUta/	*Dog*

Table 1: List of words

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Recent empirical studies (Yadav 2009) have shown that on an average the Hindi vowel phonemes /i/, /a/, /u/ have a duration that is longer than the corresponding central vowels /I, ə, U/ respectively. Table 1 above shows the data from Yadav (2009) on 10 native, monolingual speakers (5 males and 5 females) of Hindi in the age group of 15-20 years. This data has been taken as normal control. The table shows that the high front-back vowels /I - i/ and / U - u/ show a greater contrast in vowel duration in comparison with the open vowel /ə/ as against /a/ which is almost twice longer

A study by Narang et al. (2011) has reported the acquisition of vowel space by Hindi speaking children from 2 years to 5 years of age using the first two formants. The present study takes the pervious study forward and proposes to explore the contrasting acoustic space and durational contrast between three pairs of peripheral and central vowels among Hindi speaking children. For duration time (in milliseconds) and for acoustic space the first two formant frequencies have been used. This study proposes to explore the age at which the contrast in quality and the contrast in duration is acquired; the order of acquisition in terms of quality and quantity i.e. Are durational contrasts acquired first or quality in terms of F1 and F2 (tongue height and front-back in articulatory terms) is acquired first ? The data across genders i.e. male vs. female is also compared. Further, data from 10 adults (5 Males and 5 Females) was used from a similar study on acoustic space of adults conducted by Yadav (2009) as a control for this study.

The research questions this study explores are:

- At what age the duration contrast is acquired as distinctive in case of /I-i/, /U-u/ and /ə-a/ in Hindi ?
- At what age the contrast in quality in terms of F1 & F2 is acquired in case of these vowels ?
- At what age is the tongue height in terms of F1 variation becomes distinctive ?
- At what age the front-back distinction in terms of F2 or F2-F1 is acquired ?
- Is there any difference in the acquisition pattern of male and female children ?

1.1 Experiment Design

This study investigates the area of the vowel spaces used by the participants for peripheral vowels as compared to central vowels. The vowels were identified on the basis of the patterns formed by their formants within that acoustic space and how they develop gradually approximating the perceptual target.

Twenty-two male and female children, two each at the age of 2 and three each at the age of 3, 4 and 5 years participated in the study. The four groups are labelled at Group- I, II, III, and IV in this study which actually indicates the age group from 2–3, 3–4, 4–5 and 5 plus respectively. It is important to mention that as noted the parents/guardians usually indicate the age of the child in completed years rather than in years and months. For instance our groups include 2 plus as the Group-I which has four children 2.01, 2.05, 2.06 and 2.10. Similarly the Group-II consists of children up to 4 years (3 – 4 years).

The data was collected using illustrations on Microsoft Powerpoint. Wordlist commensurate with children's repertoire was prepared to include all the peripheral and central vowels preferably between two stop consonants. Recordings were made for the three peripheral and three central vowels /I, i, ə, a, U, u/ (6 words in all). Data from each child was recorded in a normal, quiet room, in presence of the child's parents or caretaker or nanny near them. A digital voice recorder Sony ICD-PX820 was used for the recordings. *Goldwave* was used for noise reduction and *PRAAT* software was used for the analysis of the sounds. The values of the first two formants namely F1 and F2, and duration were extracted. The – F1 values were plotted along the y-axis and – (F2-F1) values along the x-axis, so as to arrive at the visual representation

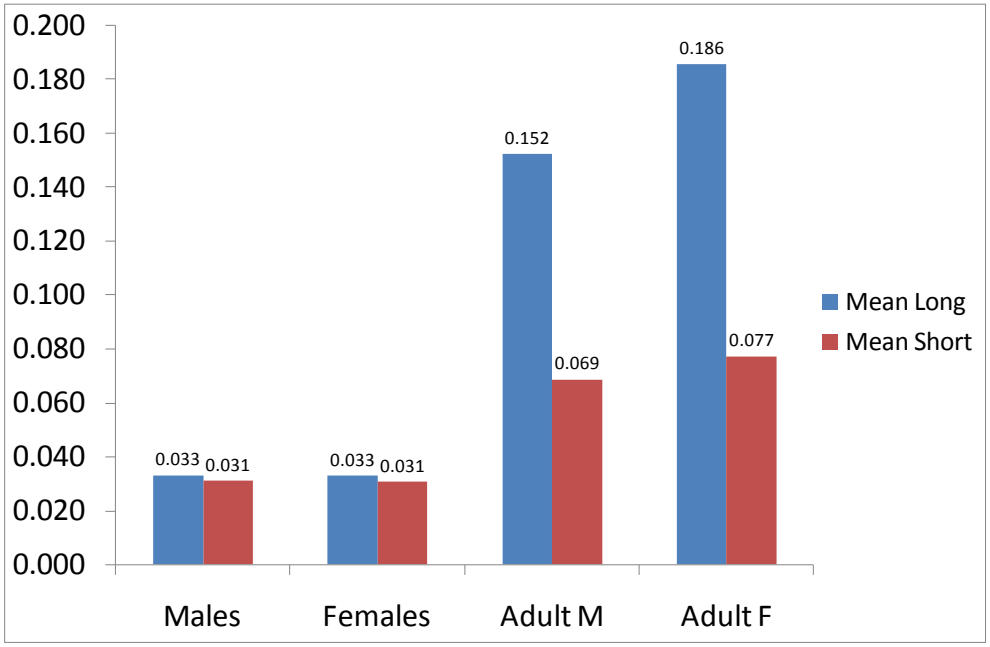
of their acoustic space corresponding to articulatory vowel space, like a cardinal vowel chart (See Table 1).

1.2 Data Analysis

Six words were repeated three times by every child. 132 samples were recorded from the children. Each of the vowels was segregated and their respective duration and formant frequencies were extracted and tabulated for further analysis (See Table 2 and Table 3 in Appendix).

2. Gender

Graph 1 shows the duration across male-female, young and adult participants. The comparison of the duration across young male and female participants shows that the average long and short contrast by participants is not defined. They are both making a negligible difference of 0.02ms between the long and short vowels which can be considered insignificant as such deviations are common even in an individual's repetition of the same vowel in the same word. Also, as compared to the control group, the participants are using a much shorter duration to differentiate the same set of vowels. This is evident from the average duration of vowels being less than 0.032ms in comparison to 0.121ms, the average duration of vowels in case of adult participants.

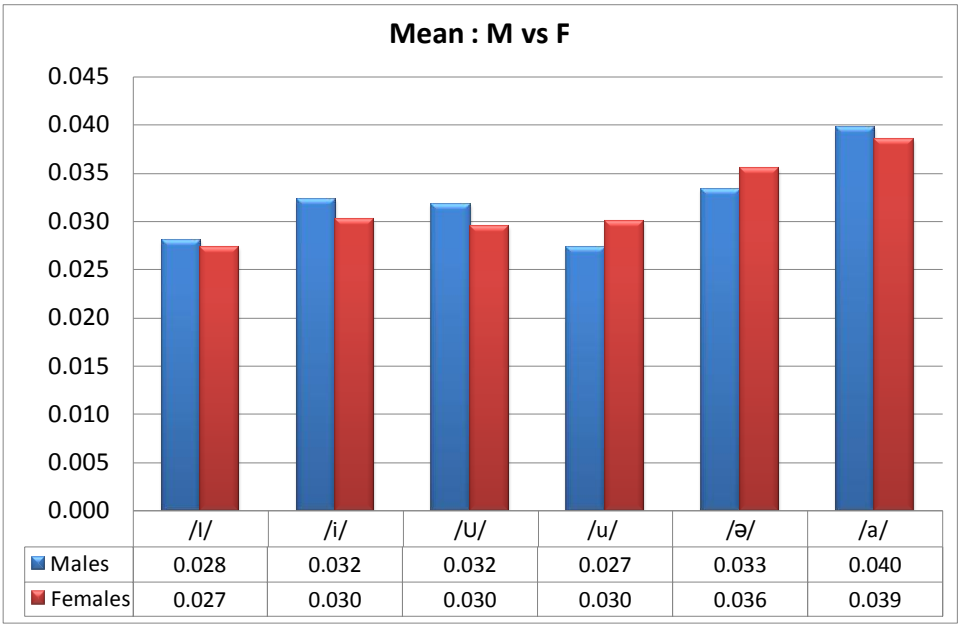


Graph 1: Mean duration of long and short vowels (in milliseconds)

If we compare the control group, the adults are using 0.169ms on an average for long vowels / i, a, u/ whereas the participants are using 0.033ms. Similarly, the short vowels /I, ə, U/ are spoken in 0.031ms by the young participants whereas the adults are using 0.073ms for the same. Thus, we can say that the younger participants are using rather short duration for all the vowels to produce both long and short vowel phonemes till 5 years of age.

Furthermore, the female (adult) participants are seen making a slightly better distinction between the long and short vowels by 0.026ms as compared to their male counterparts. Thus we may conclude that as compared to the adults, the young participants up to the age five still have

not developed a distinction between the long and short vowel contrast as far as duration is concerned.



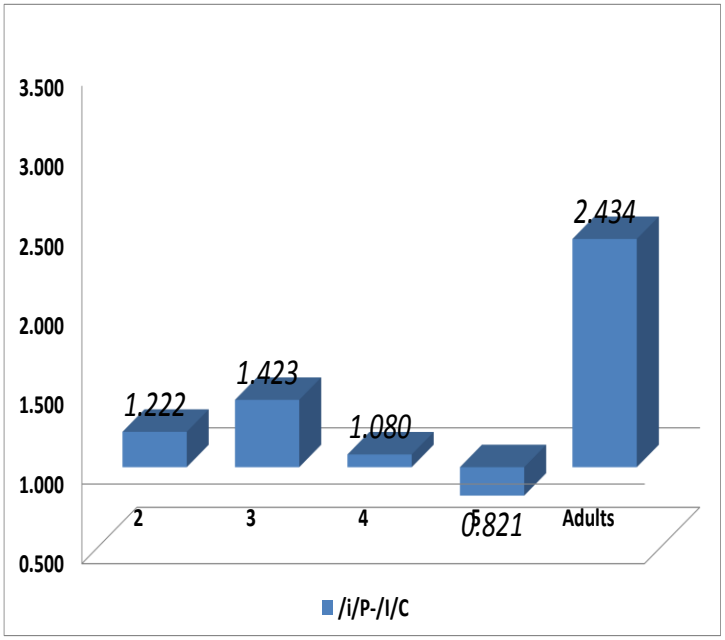
	/ɪ/	/i/	/ʊ/	/u/	/ə/	/a/
Males	0.028	0.032	0.032	0.027	0.033	0.040
Females	0.027	0.030	0.030	0.030	0.036	0.039

Graph 2: Mean duration of all vowels as spoken by young participants.

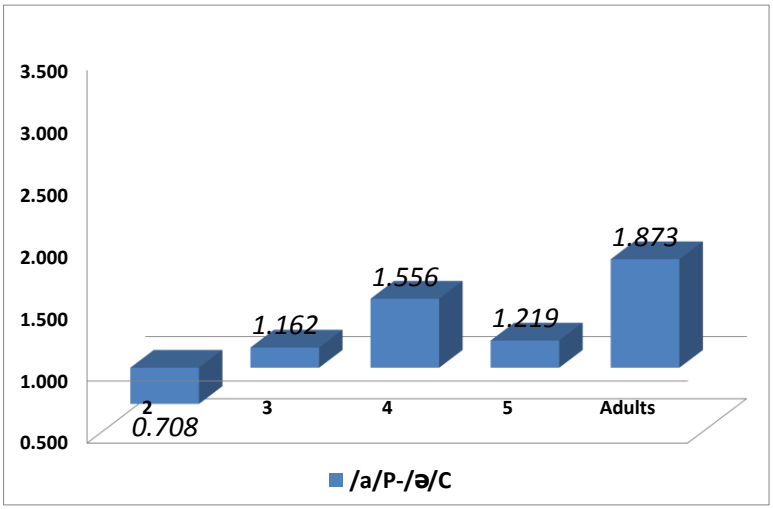
Graph 2 shows the mean duration of individual vowels (in milliseconds) spoken by male and female participants across the age group 2 to 5 years. In the case of /I - i/ both male and female participants make a difference of 0.004 and 0.003ms whereas in case of /U - u/, (- minus) 0.005 and zero ms respectively. The participants seem to be using the same duration for the high vowels /I, i, U, u/. Even for /ə - a/ the male and female are making no difference or a negligible difference of 0.007 and 0.003ms only. These negligible figures clearly show that the durational contrast is not recognized by the participants even till the age of 5 years. It is also evident from the illustration that no durational contrast among the vowels is perceived by children at such a young age.

3. Durational Contrasts: Age-wise

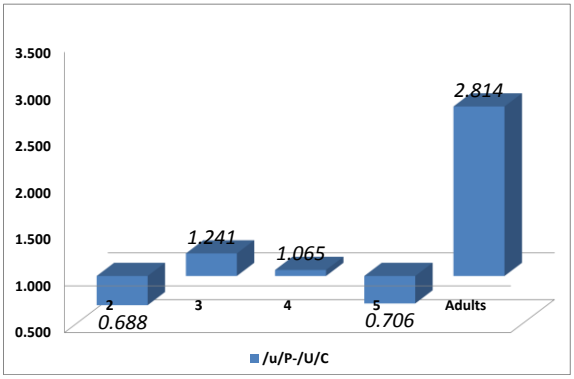
For durational contrast the ratio was obtained by dividing the duration of vowel /i/ by /I/, /u/ by /U/ and /a/ by /ə/. In some articulations where the child is articulating the central or shorter vowels as longer than the corresponding peripheral vowels the resultant values are plotted below in the graphs 3, 4 and 5 (as under) for each group of vowels. The graphs represent the durational contrast of the central and peripheral vowels /I- i /, /U - u/ and /ə – a/. Duration (in milliseconds) has been taken on Y-axis and X Axis represent the values for adult control and Group I, II, III and IV.



Graph 3: Durational contrast of /i/ - /I/ across different age groups as compared to adult control.



Graph 4: Durational contrast of /a/ - /ə/ across different age groups compared to adult control.

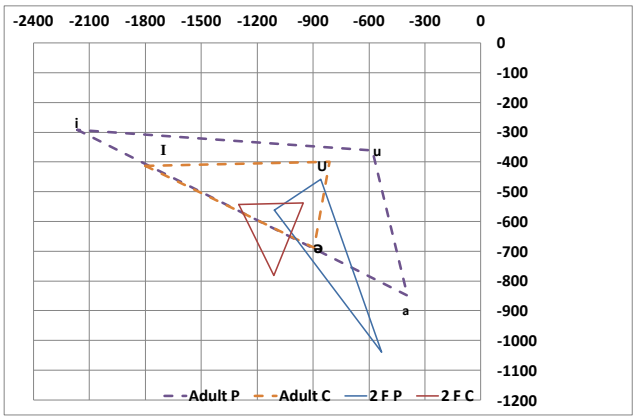


Graph 5: Durational contrast of /u/ - /U/ across different age groups compared to adult control.

The two year olds in Group -I seem to be making only about 20% longer long vowel /i/ in case of /I - i/ durational contrast, whereas they totally reverse the contrast by elongating the duration of the short vowels by 30% and 32 % less in case of /ə - a/ and /U - u/. Thus there is practically no durational contrast at this age. At the age of three the /I - i/ contrast is better defined by 40%, /ə - a/ by 62% and /U - u/ by 24%. At four years of age the participant show no contrast between /I - i/ and /U - u/ at 8% and 6 % respectively. However, they do show a 55% longer /a/ than /ə/. By the age of five years the participants seem to be elongating the short vowels /I/ and /U/ which is 18% and 30% less than the long vowels /i and u/ respectively. But just like the four year olds, the five year olds show only 21% longer /a/ than /ə/.

The control use 240% longer duration in case of /I - i/, 187% longer in case of /ə - a/ and 281% in case of /U - u/, indicates that younger participants are not yet looking at duration as a possible phonemic factor. On an average the adults use 2.1% longer duration as compared to the young participants for /I - i/ and; 1.6% and 3% longer duration for /ə - a/ and /U - u/ respectively. /ə - a/ is less than two times the length as that of /U - u/. Thus it can be said that the young participants do not show durational contrast between long and short vowels even by the age of five years. They distinguish between words by context or by pragmatics of communication rather than the phonemic contrast between long and short vowels.

4. Acoustic Spaces in Contrast: Female vs. Male children



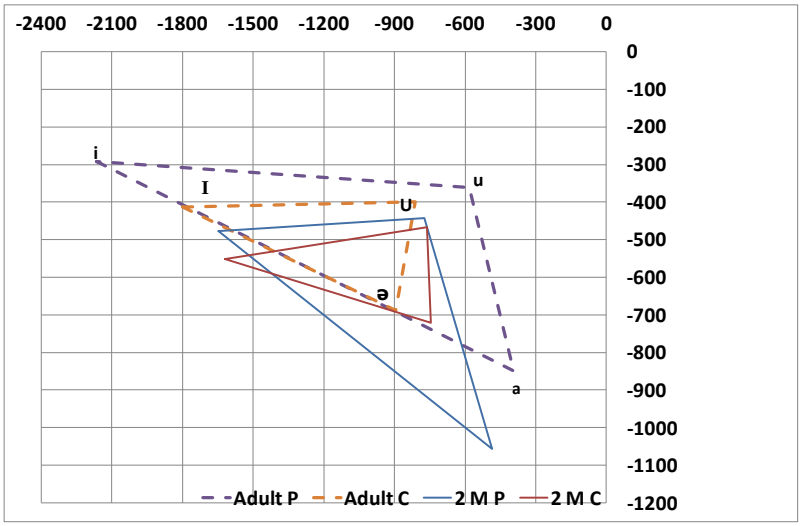


Figure 1: Acoustic Space of 2 year old Female vs. Male participants

Figure 1 shows the acoustic space of total four children in Group-I, two male and two female, two year old participants in a continuous line. The acoustic area marked with dotted line represents that of adults. The high-low contrast emerges in both male and female participants at a young age of two years, by placing /a/ distinctly at a higher F1 of 1057 and 1039 Hz by males and females, whereas the adults place them at 848 Hz.

Within this tongue height the young male participants are making a distinction between high vowels /I, i, U, u/, the central vowel /ə/ and low vowel /a/. The placement of /ə/ shows that the young female participants are placing the vowel at 780Hz and males at 721 Hz. If we compare this vowel with the high vowels we find that the young females and males are placing the vowel almost mid-way i.e. between 442-1057Hz (High-low range), similar to the adults who are placing the vowel between 291-848 Hz at 687Hz. Thus a three way contrast can be seen emerging in tongue height of young participants with the range of High, Mid and Low vowel.

The female participants were found using a very limited front-back range of 249 Hz (858-1107 Hz) which is nearly one-third in comparison to the average adults (See dotted lines) who usually use a much broader range for high vowels of 1581 Hz (581-2162Hz). The four vowels /I, i, U, u/ are being produced with a nominal difference. In comparison to the two year old female, the male participants are using a broader front-back range of 858 Hz (761-1619) with /u - U/ high back vowels at 760 Hz and /I - I/ high front vowels at 1620 Hz, /a/ is placed between 484-533 Hz which is being used as a back vowel, like the adults who are using 395 Hz for producing the same vowel.

Thus at the age of two years the young female participants are just beginning to make distinction between front-back vowels with 300-350Hz range, while high-low contrast can be clearly seen. The male children show high-low contrast between /I - u/ and /a/ plus an increased range of approximately 900-1000Hz for front-back contrast in high vowels. All the male and female children do show a difference of acoustic space used for peripheral vs. central vowels although the two year old male children show the placement of /I - i/ and /U - u/ around the same place, but /ə/ & /a/ in the central space.

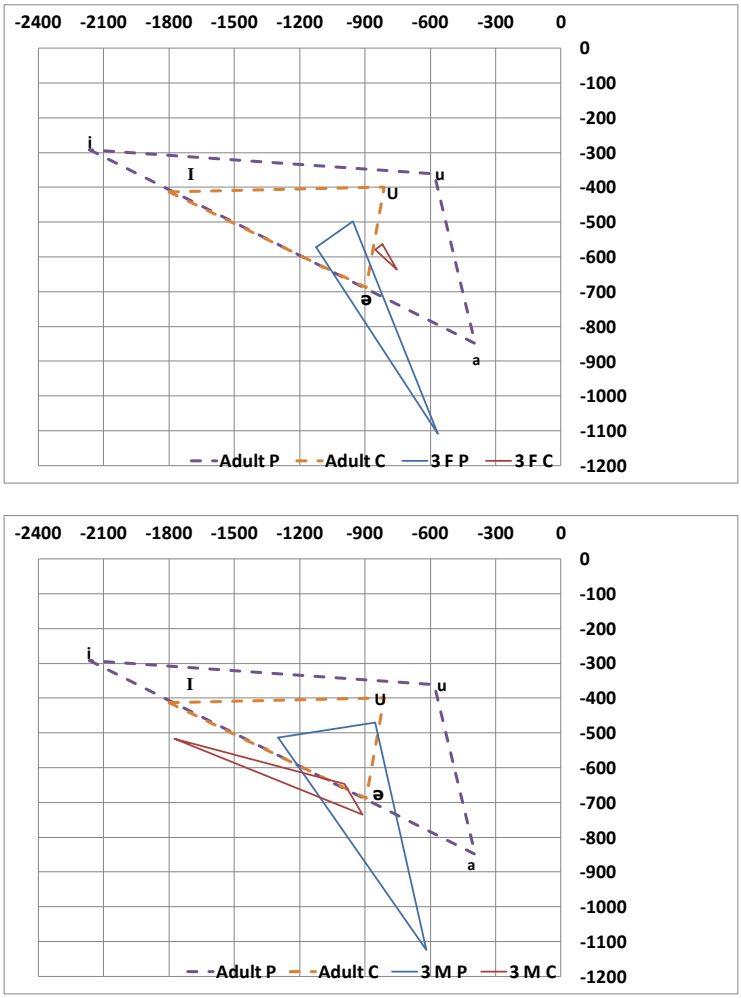


Figure 2: Acoustic Space of 3 year old Female vs. Male participants

Figure 2 shows the acoustic space of total six children in Group -II, three male and three female, three year old participants. At this age the participants show an entirely different pattern. Both males and females are seen distinguishing /a/ clearly from the high vowels /I - i/ and /U - u/ at the tongue height of 1109-1123 Hz. The high-low contrast is very evident.

The placement of /ə/ short, central vowel shows that the young female participants are placing the vowel at 637 Hz fairly close to the high vowels in the range of 500-600Hz, and males at 735 Hz which is in the middle of the high vowels in the range of 500-525 Hz and open low vowel /a/ at 1123 Hz whereas the adults are found placing the mid vowel at 687Hz. Thus, we can say that placement of this vowel is well within the range as that of adults and a three way contrast can be seen emerging in tongue height of these young participants with the range of High, Mid and Low vowel. In comparison, the young males seem to be differentiating and placing /ə/ at 735 Hz, almost mid-way between high vowels at 469Hz and low vowel at 1123 Hz.

The female participants are using a very limited area/space for producing the four high vowels and one central vowel /I, i, U, u/ all in the front-back range of merely 306 Hz (819-1125). The males on the other hand use a wider range of 922 Hz to place the same set of high vowels. This space is very small as compared to that used by the adult control group who are using a range of

1581 Hz (581-2162Hz).Also, the short vowel /I/ placed outside the vowel space, as more peripheral as compared to /i/ indicating that the phonemic contrast between /I - i/ does not match or correspond to the phonetic – qualitative contrast. Similarly, the /U - ə/ being close to each other in the vowel space also indicates that the central vs. peripheral quality contrast is yet to appear in 3 years old output. Also, /a/ is placed between 565-618 Hz on F2-F1 scale, which is being used as a back low vowel, in comparison to the adults who are using 395 Hz for producing the same vowel.

It is also important to note that the female participants are seen placing the central vowels /I, ə, U/ in a different space altogether as compared to the peripheral vowels /i, a, u/. Rather what is most prominent is the minimal space being used by them for all the central vowels, perhaps at this stage the participants are still redefining the space and the position of the vowels and marking the difference between these sets of vowels but it is evident that the young participants seem to have developed a clear contrast between high-low vowels only while the front-back contrast for high and mid vowels remains quite fluid.

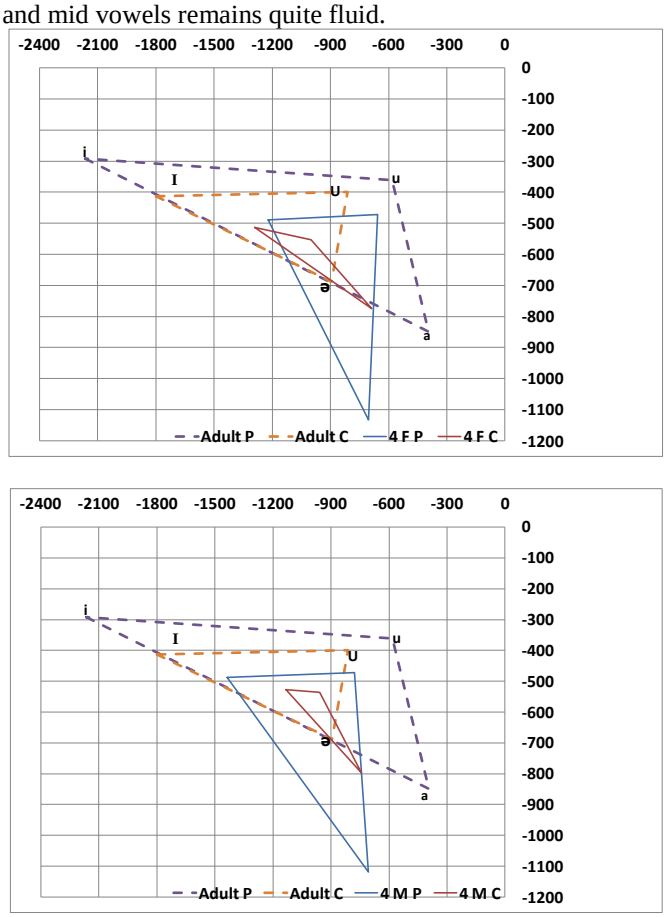


Figure 3: Acoustic Space of 4 year old Female vs. Male participants

Figure 3 shows the acoustic space of total six children in Group-III, three male and three female, four year old participants. At this age the participants continue to show a high-low vowel distinction. Both male and female participants are using a wider range of 647 Hz (472-1119 Hz) for high-low contrast as compared to the adult control that is using 557Hz (291-848). Thus, the vowels by tongue height criteria are well defined, distinguished at this stage by the participants.

They also show a clearer distinction between high vowels /I, i, U, u/ and central mid vowel /ə/ by placing it between 637-796 Hz by females and males, which is almost halfway the high-low range.

With the progression in age from two to three and three to four, the participants are using a wider front-back range to place the vowels. The female and male participants are using a roughly similar front-back range of 566 Hz (656-1222) and 660 Hz (777-1437) respectively for high vowels. In comparison to the two and three year olds, the females at the age of four show a progression by using a wider frequency range for front-back vowels, with a clear distinction between front-back high vowels.

Also the vowel /a/ seems to be more centrally placed at 704-706 Hz on F2-F1 (X-axis) by the young participants, as compared to the adults who place it at 848 Hz as compared to the earlier groups like the two year olds who placed it at 533 and 484, 565 and 618 by three year olds.

The three central vowels together are now beginning to show. The emergence of a central space within a well defined peripheral vowel space, although both the acoustic spaces are smaller as compared to those of the normal adult speakers of the language.

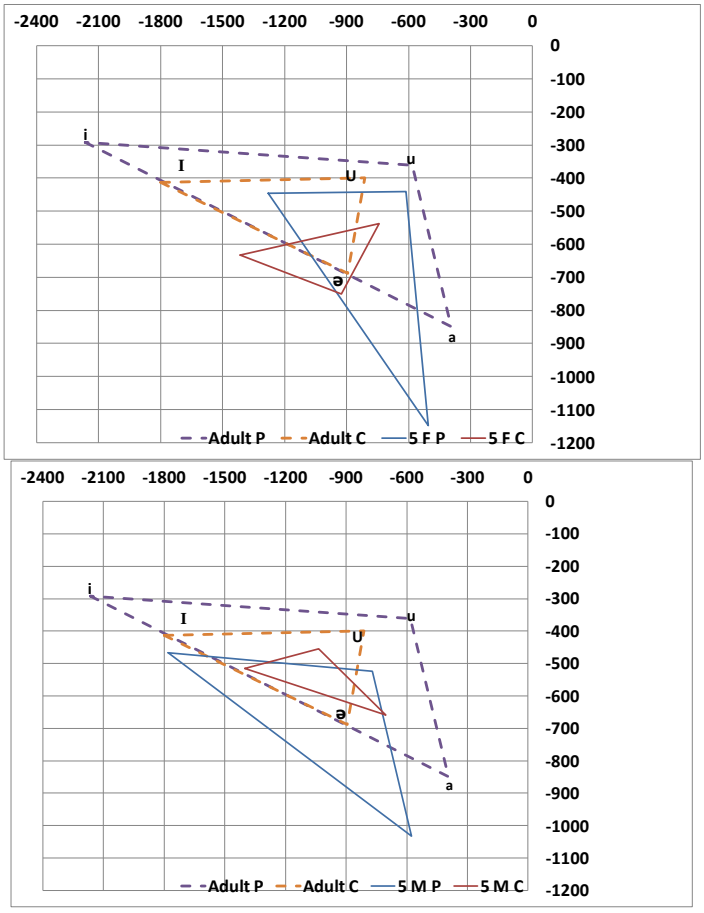


Figure 4: Acoustic Space of 5 year old Female vs. Male participants

Figure 4 shows the acoustic space of total six children in Group-IV, three male and three female. High-low contrast is well defined with the males using a range of 565 Hz (from 467-1032), females using the range of 708 Hz (441-1149) and adults at 557 Hz (291-848). In this

high-low contrast the young male and female participants are placing /ə/ at 659 Hz and 750Hz respectively, whereas the adults seem to be placing it at 687 Hz. It is all midway between front and low vowels.

Moreover, the females have placed the high vowels in the front-back range of 667 Hz (612-1279) and the males at 1010 Hz (770-1780), where the male children are nearing to the range used by adults i.e. of 1581 Hz (581-2162 Hz). All the participants in comparison to the two, three and four year olds show usage of wider acoustic space for high vowels at the age of five years. Also, /a/ is being placed at 504-576 Hz on F2-F1 (X- Axis), which is not so far back as compared to the adults who place it at 395 Hz.

5. Main Findings and Observations

With regards to the age at which durational contrast appears as a distinctive phonemic feature, the data obtained from the twenty two children in the present study shows that even in Group-IV the children produce the long/peripheral and short/central vowels with practically no difference of vowel length. Even if they do perceive these as distinct phonemes due to their vowel quality or context or any other feature, they do not produce these vowels as long and short vowels in contrast.

This study attempted to seek several answers to the research questions pertaining to the acquisition of vowel quality in terms of tongue height and front-back criteria measured in terms of (F1 and F2-F1 respectively) formant values of the phonetic output. Firstly, *At what age does the contrast in quality in terms of F1 & F2 is acquired in case of these vowels?* was examined where F1 indicating the tongue height (high-low or close-open feature of the vowel) is acquired first but the entire vowel space takes time to develop. Secondly, referring to acquisition of this feature we find that even the youngest participants, 2 male and 2 female children in the age Group-I show distinction between High and Low vowels. In fact it is /a/ open vowel at approximately 1000 Hz in contrast with several high/close vowels clustered together in the range of 550-600 Hz F1 values. Thirdly, *At what age the front-back distinction in terms of F2 or F2-F1 is acquired?*. The front-back criteria begins to emerge for the peripheral vowels at the age of two but it takes better shape only by the age of five years perhaps up to six years because Group-IV includes children up to 5 years 11 months for the peripheral vowels. It is evident that participants in the first three groups are using a small range for front-back contrast which gradually develops showing a well defined vowel space for peripheral vowels, although it is still smaller than the adult's vowels space. For the central vowel's acoustic space begins to take shape much later. In comparison with the adults acoustic space the participants even at the age of five are operating within a small space. Also it is evident that the quality in the vowels develops first and its only later that quantity begins to develop. The participants show a clear contrast in the high-low distinction between both central and peripheral vowels right from Group-I under study. However, such is not the case when it comes to the distinction of front-back vowels. Lastly, we have an equal number of male and female participants in each group. The two youngest male participants (at 2.06 and 2.10) seem to be exceptional because their acoustic space contrast in F1 (High and Low) F2-F1 front and back is much better than the other participants in their own group that is the female participants in their group as well as others in Groups II, III and IV (See figures below). Because of this reason we have clubbed together the male and female data to arrive at the acoustic spaces of peripheral and central vowels in Groups I, II, III and IV the acoustic space for central vowels seems to be better in Group-I, and Groups II, III and IV follow a gradual development of central vowel space. (See figures below). Quantification of acoustic area and that too irrespective of gender shows central and peripheral acoustic spaces developing gradually with age from 2 years to 6 years.

5.1 ACOUSTIC SPACES IN CONTRAST: AGE GROUPS

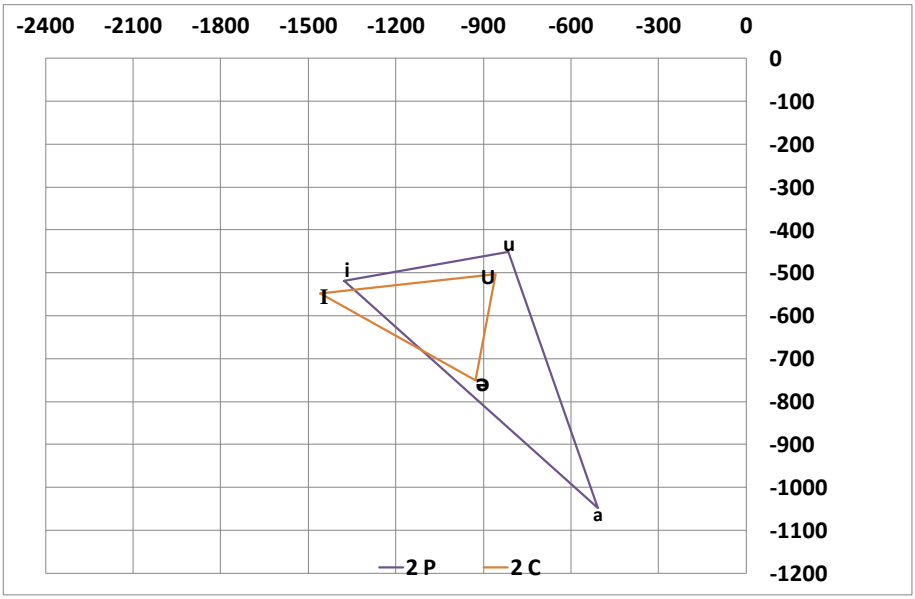


Figure 5: Acoustic Space of participants in Group-I

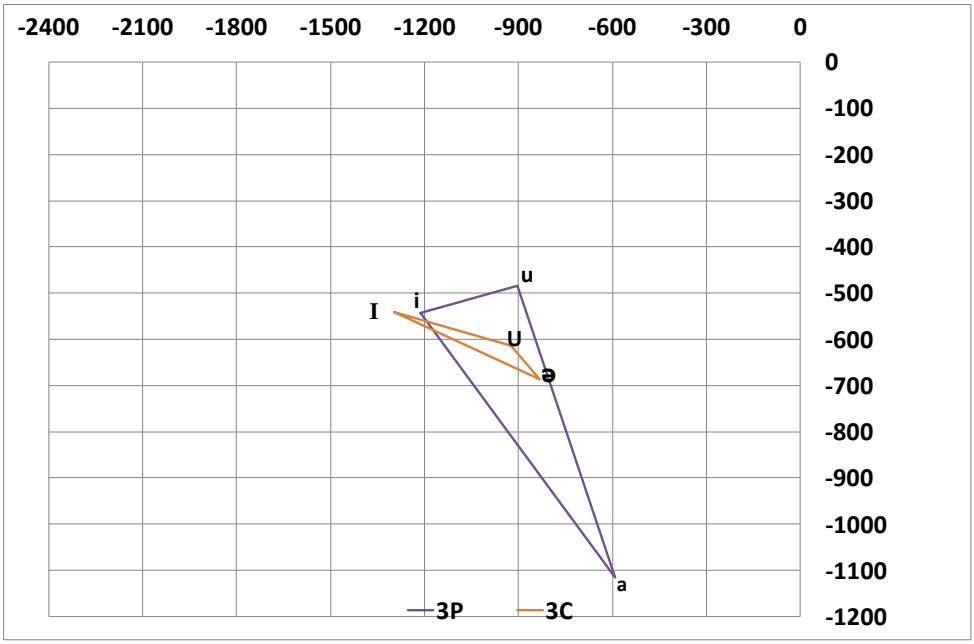


Figure 6: Acoustic Space of participants in Group-II

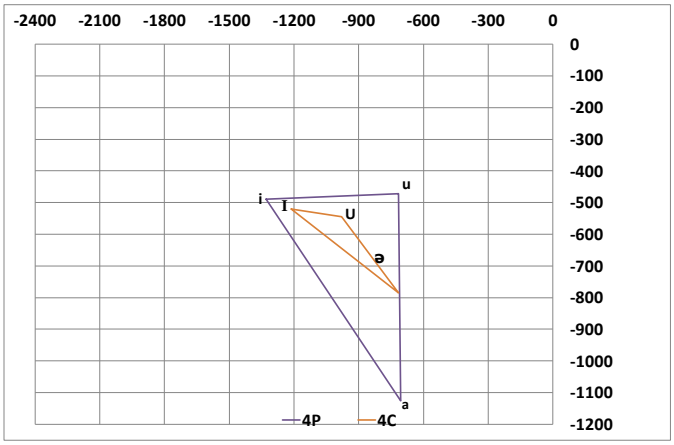


Figure 7: Acoustic Space of participants in Group-III

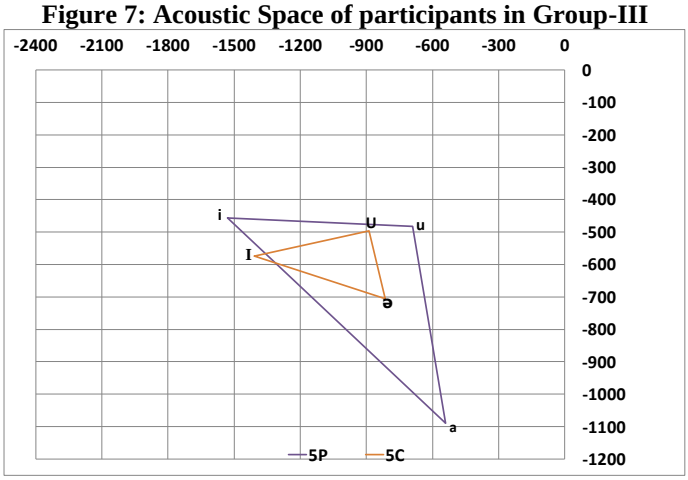
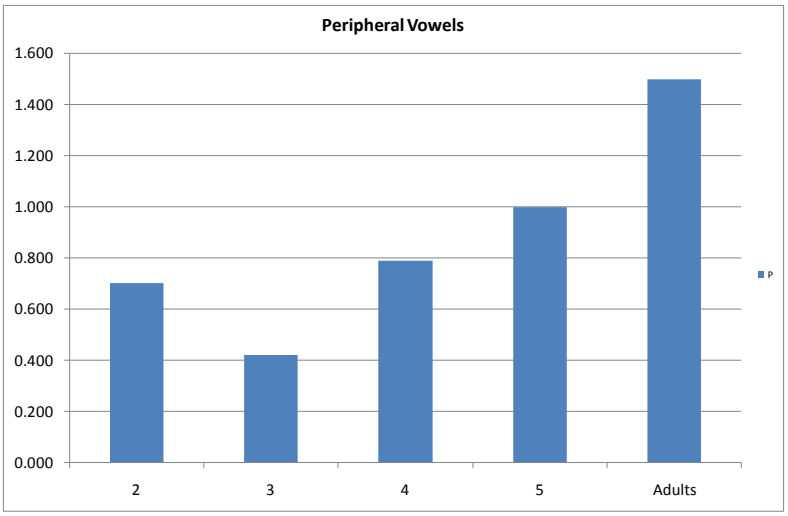
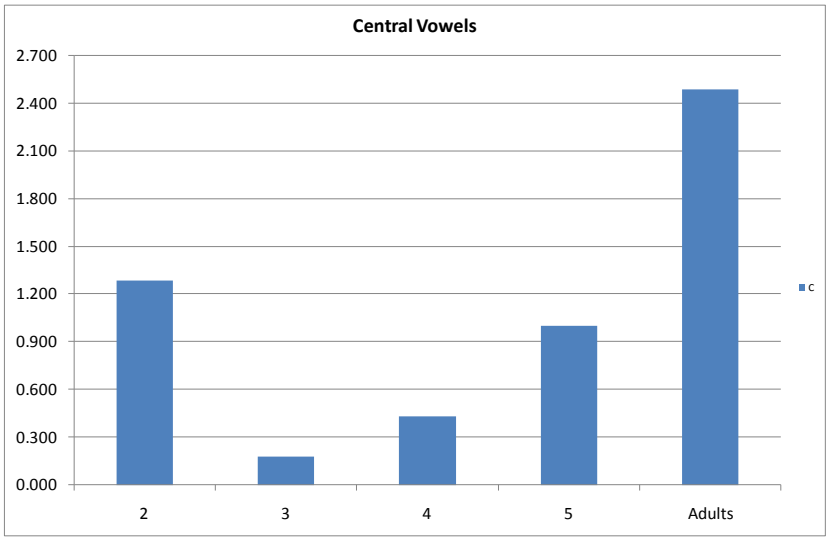


Figure 8: Acoustic Space of participants in Group-IV



Graph 6: Acoustic Area of Peripheral Vowels



Graph 7: Acoustic Area of Central Vowels

The acoustic space (using the Irregular Polygon Area Calculator) was calculated for the respective age groups and adults. Taking 5-6 year old (Group IV) as one, the acoustic area of all other groups was determined in relative terms. As can be seen in the Graph 6 for peripheral vowels the 5-6 year olds acoustic area vis – a – vis adult's vowel space is 1:1.5, and with reference to the same Group-IV the younger groups show 1:0.79:0.42:0.70. This indicates that the acoustic area of Group-III is only 21% less than that of Group-IV and the acoustic area of Group-II at 42% is nearly 58% less than the Group-IV. The performance of the youngest group as discussed earlier was better at 0.70 i.e. only 30 % less than Group-IV, especially so with the peripheral vowels.

In case of central vowels with reference to the Group-IV, the younger groups showed 1:0.43:0.18:1.28, which shows that the youngest children did perform much better than even 5 year olds with 28% more acoustic space of central vowels. The other two groups show a gradual progression from 18% (Group-II) to 43% (Group-III). In any case all participants show that the acoustic space of central vowels is still much less than that of the adults, which is 248% more than that of the oldest Group-IV.

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APPENDIX

TABLES

Males	/I/	/i/	/U/	/u/	/ə/	/a/	Avg. All	Avg. Short	Avg. Long
2	0.019	0.044	0.028	0.022	0.031	0.031	0.029	0.026	0.032
3	0.027	0.035	0.031	0.031	0.044	0.038	0.034	0.034	0.035
4	0.033	0.027	0.035	0.031	0.031	0.046	0.034	0.033	0.035
5	0.033	0.023	0.033	0.025	0.027	0.044	0.031	0.031	0.031
Avg.	0.028	0.032	0.032	0.027	0.033	0.040	0.032	0.031	0.033
Adult M	*0.065*	*0.145*	*0.054*	*0.167*	*0.087*	*0.145*	*0.111*	*0.069*	*0.152*
Females	/I/	/i/	/U/	/u/	/ə/	/a/	Avg. All	Avg. Short	Avg. Long
2	0.038	0.025	0.022	0.013	0.044	0.022	0.027	0.035	0.020
3	0.027	0.042	0.029	0.044	0.033	0.052	0.038	0.030	0.046
4	0.019	0.029	0.029	0.038	0.025	0.042	0.030	0.024	0.036
5	0.025	0.025	0.038	0.025	0.040	0.038	0.032	0.034	0.029
Avg.	0.027	0.030	0.030	0.030	0.036	0.039	0.032	0.031	0.033
Adult F	*0.078*	*0.205*	*0.073*	*0.183*	*0.081*	*0.169*	*0.132*	*0.077*	*0.186*

Table 2: Duration (in milliseconds)

S.No.	**CODE**	**/i/**	**/i/**	**/a/**	**/a/**	**/u/**	**/u/**	**/I/**	**/I/**	**/ə/**	**/ə/**	**/U/**	**/U/**
		- F1	**- F2**	**- F1**	**- F2**	**- F1**	**- F2**	**- F1**	**- F2**	**- F1**	**- F2**	**- F1**	**- F2**
1	**F2.01Pu**	-558.0	2097.9	-1062.1	1808.9	-413.1	1507.2	-587.0	1895.9	-747.2	2013.0	-613.3	1571.6
2	**F2.05EB**	-566.0	1240.8	-1015.4	1335.7	-504.2	1126.7	-498.8	1788.2	-814.4	1772.1	-462.7	1409.7
2F	**Avg.**	**-562.0**	**1669.4**	**-1038.7**	**1572.3**	**-458.7**	**1317.0**	**-542.9**	**1842.1**	**-780.8**	**1892.5**	**-538.0**	**1490.6**
3	**F3.00SG**	-465.5	1552.1	-1244.8	1928.4	-464.0	1441.9	-470.6	1503.3	-515.5	1527.1	-542.7	1619.7
4	**F3.04DM**	-672.9	2030.6	-1043.2	1803.2	-442.0	1679.5	-533.7	1322.7	-698.1	1468.3	-510.3	1420.6
5	**F3.08AK**	-577.2	1508.1	-1039.7	1293.7	-589.5	1238.8	-688.7	1324.6	-697.4	1178.4	-684.6	1253.4
3F	**Avg.**	**-571.9**	**1697.0**	**-1109.2**	**1675.1**	**-498.5**	**1453.4**	**-564.3**	**1383.6**	**-637.0**	**1391.3**	**-579.2**	**1431.2**
6	**F4.00DG**	-489.3	1582.8	-1073.2	1963.1	-559.3	1132.5	-590.8	2747.4	-747.2	1625.8	-604.6	1613.8
7	**F4.01AT**	-477.4	1448.4	-1230.4	1844.7	-415.9	1342.5	-495.9	1511.0	-876.9	1303.5	-575.3	1791.6
8	**F4.08AK**	-499.	2099.2	-1093	1702.1	-441.	912.0	-451.	1152.5	-699.	1455.5	-479.	1256.8

		2		.7		8		2		8		3	
4F	**Avg.**	**-488.6**	**1710.1**	**-1132.4**	**1836.6**	**-472.4**	**1129.0**	**-512.6**	**1803.7**	**-774.6**	**1461.6**	**-553.1**	**1554.1**
9	**F5.00PS**	-405.0	1539.3	-1151.2	1942.5	-444.6	1118.1	-805.7	2168.7	-765.4	1539.9	-498.7	1204.3
10	**F5.04AG**	-420.4	1720.1	-1113.2	1297.3	-445.7	1173.7	-436.7	1542.3	-539.2	1625.8	-453.8	1529.6
11	**F5.07KJ**	-513.3	1917.6	-1181.4	1720.6	-433.5	869.9	-654.1	2425.8	-946.1	1858.9	-660.0	1105.59
5F	**Avg.**	**-446.2**	**1725.6**	**-1148.6**	**1653.5**	**-441.3**	**1053.9**	**-632.2**	**2045.6**	**-750.2**	**1674.9**	**-537.5**	**1279.8**
1	**M2.06NM**	-386.9	1535.2	-1101.1	1404.3	-340.7	1484.7	-524.0	1536.6	-795.3	1654.7	-436.3	1513.4
2	**M2.10DH**	-566.2	2710.8	-1012.0	1677.7	-544.4	945.4	-580.1	2804.9	-648.0	1279.0	-496.7	943.0
2M	**Avg.**	**-476.6**	**2123.0**	**-1056.6**	**1541.0**	**-442.6**	**1215.0**	**-552.1**	**2170.8**	**-721.7**	**1466.8**	**-466.5**	**1228.2**
3	**M3.02PG**	-388.2	1343.2	-1154.7	1861.2	-463.7	1288.3	-524.0	3022.1	-979.1	1950.3	-672.3	1510.4
4	**M3.07AS**	-533.4	2421.0	-1199.3	2174.3	-383.7	1574.2	-410.7	1644.8	-586.0	1484.4	-610.4	1470.3
5	**M3.11DK**	-621.2	1677.3	-1016.2	1190.9	-561.7	1107.0	-616.2	2208.5	-640.0	1501.4	-658.2	1941.5
3M	**Avg.**	**-514.3**	**1813.8**	**-1123.4**	**1742.1**	**-469.7**	**1323.2**	**-517.0**	**2291.8**	**-735.0**	**1645.3**	**-647.0**	**1640.7**
6	**M4.01RB**	-462.3	1534.4	-1057.2	1655.4	-687.6	1390.6	-575.0	1536.6	-754.2	1392.9	-617.9	1395.0
7	**M4.05AB**	-472.0	2170.4	-1167.2	1881.5	-469.9	1204.8	-572.8	1543.8	-825.1	1478.6	-578.6	1368.4
8	**M4.09AR**	-530.3	2069.9	-1134	1940.0	-260.4	1154.3	-434.6	1898.8	-809.6	1748.7	-411.2	1716.8
4M	**Avg.**	**-488.2**	**1924.9**	**-1119.5**	**1825.6**	**-472.6**	**1249.9**	**-527.5**	**1659.8**	**-796.3**	**1540.1**	**-535.9**	**1493.4**
9	**M5.01AG**	-344.2	1600.1	-1044.8	1545.2	-464.7	1094.4	-465.6	1276.3	-733.3	1593.8	-447.5	1300.6
10	**M5.05DB**	-492.	3042.9	-1127	1719.9	-550.	1166.3	-563.	2854.0	-620.	1048.3	-573.	1716.4

		6		.3		3		0		9		5	
11	**M5.11 PJ**	-563.9	2096.6	-924.6	1560.6	-554.0	1619.7	-514.6	1618.9	-623.3	1445.2	-343.1	1452.5
5M	**Avg.**	**-466.9**	**2246.5**	**-1032.2**	**1608.6**	**-523.0**	**1293.4**	**-514.4**	**1916.4**	**-659.2**	**1362.5**	**-454.7**	**1489.9**

Table 3: Formant Frequencies of Male and Female participants

	ADULT AVERAGE		FEMALE		MALE	
	-F1	-(F2-F1)	-F1	-(F2-F1)	-F1	-(F2-F1)
/i/	-291.25	-2162.87	-293.92	-2379.79	-288.57	-1945.94
/I/	-412.37	-1799.75	-429.72	-1936.88	-395.01	-1662.62
/ə/	-687.64	-894.24	-736.77	-946.09	-638.51	-842.38
/a/	-848.77	-395.07	-881.20	-427.82	-816.34	-362.32
/u/	-360.61	-581.92	-387.66	-635.64	-333.55	-528.19
/U/	-399.33	-812.01	-409.71	-849.78	-388.94	-774.23

Table 4: Formant Frequencies of adult control group.

	VOWEL	2F	3F	4F	5F	2M	3M	4M	5M
/i/	–F1	-562.1	-571.9	-488.7	-446.3	-476.6	-514.3	-488.3	-467
	– (F2-F1)	-1107	-1125	-1222	-1279	-1646	-1300	-1437	-1780
/a/	–F1	-1039	-1109	-1132	-1149	-1057	-1123	-1119	-1032
	– (F2-F1)	-533.6	-565.9	-704.2	-504.9	-484.4	-618.7	-706.2	-576.4
/u/	–F1	-458.7	-498.6	-472.4	-441.3	-442.6	-469.7	-472.7	-523
	– (F2-F1)	-858.3	-954.9	-656.6	-612.7	-772.5	-853.5	-777.3	-770.5
/I/	–F1	-542.9	-564.4	-512.7	-632.2	-552.1	-517	-527.5	-514.5
	– (F2-F1)	-1299	-819.2	-1291	-1413	-1619	-1775	-1132	-1402
/ə/	–F1	-780.8	-637	-774.7	-750.3	-721.7	-735.1	-796.4	-659.2
	– (F2-F1)	-1112	-754.3	-687	-924.6	-745.2	-910.3	-743.8	-703.3
/U/	–F1	-538.1	-579.2	-553.1	-537.6	-466.6	-647	-535.9	-454.7
	– (F2-F1)	-952.6	-852.1	-1001	-742.3	-761.7	-993.8	-957.5	-1035

Table 5: Formant Frequencies of young participants group.

Area	2	3	4	5	Adults
P	178138.9	106599.7	200092.7	252924.4	379398.3
C	73303.5	10361.7	24779.5	57021.1	141854.7
Ratio	2	3	4	5	Adults
P	0.704	0.421	0.791	1.000	1.500
C	1.286	0.182	0.435	1.000	2.488

Table 6: Acoustic Area of Young participants and adult control group.

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