

## The effect of age and sex on the acoustic characteristics of speech

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### Abstract

*This research aims to investigate the effects of age and sex on some acoustic features of speech sounds including fundamental frequency (F0), formants (F1 and F2), intensity and duration. To do this, twenty four Persian-speaking participants (12 male and 12 female) were asked to utter 36 CVC isolated words. Syllables consisted of six Persian plosives /p/, /t/, /k/, /b/, /d/ and /g/ and six vowels /æ/, /e/, /o/, /a/, /u/ and /i/; thus, every syllable had two similar plosives plus a vowel in between. Syllables were recorded in a sound-proof room using Praat Software. All acoustic properties were measured using spectrogram and oscillogram. Results showed that duration of vowels in teenagers was longer than that in adults; moreover, females had longer duration than males. Concerning formants, F1 of all vowels was more in children than in adults except for /o/. Intensity of men was more than that of women and F0 was less in middle-aged people than in young people and it was more in women than in men.*

**Keywords:** *Duration, intensity, formant, fundamental frequency*

### 1. Introduction

Biologically, humans differ in terms of sex and age. Like other organs, larynx and vocal cords undergo some changes resulted from age and sex. These changes can affect some features including intensity, duration, fundamental frequency and formants. Numerous studies have shown that F0 and F1 decrease with age, while F2 and F3 remain unchanged or even increase slightly (Harrington, 2006; Harrington et al 2007; Mwangi, et al 2009). It shows that fundamental frequency and the first formant are highly dependent on physiological and anatomical features of vocal tract and on the way the articulators are controlled (Iseli et al 2007). As mentioned earlier, the reason

why formants decrease with age is due to the fact that vocal tract lengthens and thus the larynx lowers (Laver and Trudgill, 1979; Linville, S. E. 2001). Similarly, Xue and Hao attribute this decline to increased length of vocal tract and oral cavity in elderly people compared to younger ones (Xue and Hao 2003). Intensity which is another feature of voice quality is affected by F1 and F2; vowels which have close F1 and F2 have more intensity than those with far F1 and F2 (Kondo, 2005). Moreover, age and sex can also have some impacts on duration of vowels. Men and women have shorter durations than children, with men having the shortest of all (Hillenbrand et al 1995; Smith, 1978)

This work aims to investigate the effects of sex and age on some features of vowels (e.g. F0, formants, intensity and duration) uttered in CVC Persian segments, focusing mostly on the influence of formants on their neighboring plosives.

## **2. Participants**

Twenty four Persian native speakers (twelve males and twelve females) participated in this research. All participants underwent respiratory and laryngeal examination and were considered (confirmed) healthy. Before conducting the test, written informed consent was obtained from all subjects and they were assured that this information was confidential and would be used only for this research and only to achieve the certain objectives. To do this, some young people (girls and boys) with the mean age 14 and some old people (men and women) with the mean age 65 were selected randomly. After their respiratory health was checked and diagnosed healthy, they were asked to utter the above-mentioned segments. Then, all features were calculated using Praat.

## **3. Method**

In order to perform the test, all participants were asked to attend a sound-proof room and were asked to utter 36 CVC words consisting of six Persian plosives (p, t, k, b, d and g) plus six vowels of /æ, e, u, a, u and i/ in a way that both Cs in a word were kept constant and the vowels changed. Each word was recorded twice using Praat Software and the high-quality one was

selected as the required word. In order to analyze the data, Repeated Measure Anova has been used.

#### 4. Results

After all words were recorded, their formants, intensity, duration and F0 were analyzed.

##### 4.1 Duration

An analysis of variance was performed on the durations of vowels [a, æ, u, I, o, e] with AGE (adult vs. teenager) and SEX ( male vs. female) as factors. Muchley’s test of sphericity shows that none of the factors or interactions was significant. The results show that there were a main effect for AGE ( $F(1,19)=6.72$ ,  $p < 0.01$ ) and SEX ( $F(1,19)=5.77$ ,  $P < 0.01$ ).

Table 1. Mean duration and standard deviation (in parenthesis), in ms, of vowels

<b>Age</b>				
adult		teenager		
Sex	Male	Female	Male	Female
	211(41)	206(54)	207(57)	242(40)

Table 2. The effect of sex and age on the duration of vowels

<b>Sex</b>	<b>Age</b>
F=6.72*	F=5.77*

\*P<0.01

Table 2 shows that sex influences the duration of vowels. The duration of vowels in teenagers is 29ms longer than that in adults (see fig. 1).

The effect of sex is also important. The results show that the duration of female’s vowels are 24 ms longer than that of males (see fig. 2). While interaction of age and sex is not significant but the results show that vowel

duration decreases with aging. Longer duration of teenagers expected based on the results of Smith (1978), Kent and Forner(1980) and Hillenbrand et al (1995). They indicated that younger people produce longer vowels comparing with adults. Regarding sex, these results are in line with the study by Hillenbrand et al (1995).

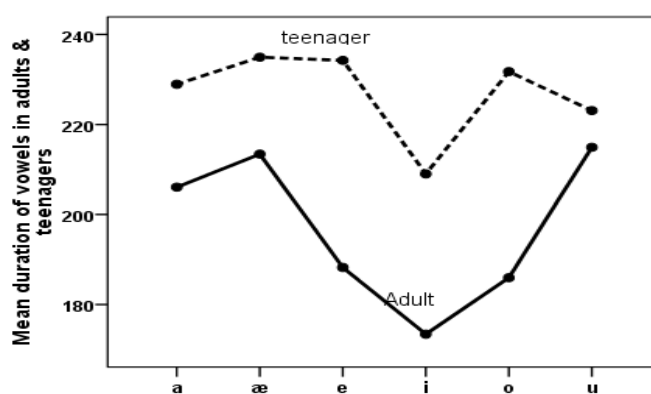


Figure 1. Duration of vowels in teenagers and adults

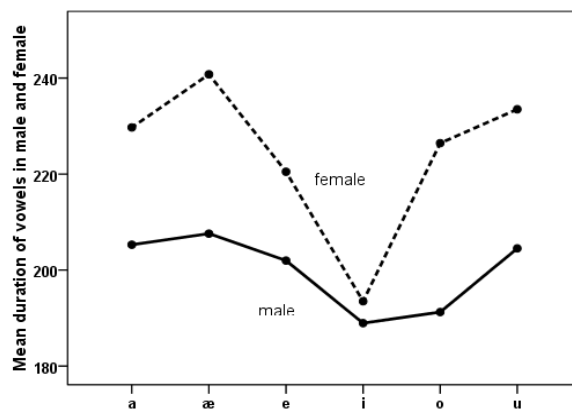


Figure 2. Duration of vowels in males and females

## **4.2 Formant frequencies**

An analysis of variance (repeated measures) was performed on the F1 and F2 of vowels [I, a, o, e, u, æ] of the segmented sections of the target words with AGE (teenagers vs. adults) and SEX (male vs. female) as factors.

Vowel [a]: The effects of AGE ( $F(1,23)=16.13$ ,  $p<0.001$ ) and SEX ( $F(1,23)=14.38$ ,  $p<0.001$ ) on F1 of vowel [a] are significant. The results indicate that F1 of vowel [a] in teenagers is 27.12Hz higher than that in adults and F1 of females is 28 Hz higher than of males (see fig. 3). The significant effect of AGE ( $F(1,19)=39.55$ ,  $p<0.01$ ) on F2 of vowel [a] shows that the second formant of this vowel in adults is 154 Hz lower than that in teenagers. Results are in line with the results of a study by Hillenbrand et al., (1995).

Vowel [i]: Reviewing the effect of age on F1 of vowel [i] reveals that it is 78Hz more in teenagers than in adults. Moreover, the effect of AGE ( $F(1,23)=16$ ,  $p<0.01$ ) and SEX ( $F(1,23)=14.38$ ,  $p<0.001$ ) on the first formant shows that F1 in females is 78Hz more than that in males. Table 3 shows that the effects of AGE ( $F(1,23)=5.73$ ,  $P<0.01$ ) and SEX ( $F(1,23)=50.11$ ,  $P<0.001$ ) on F2 of vowel [i] is significant. Results show that F2 of [i] in adults is 67Hz more than that in teenagers. In addition, it is 181Hz more in males than in females (see fig.4).

It is consistent with the studies carried out by Torre and Barlow (2009) and Hillenbrand et al., (1995). Regarding sex, these results are in line with the results of a study conducted by Iseli et al., (2007). These results are in contrast with the results of study by Torre and Barlow (2009).

Vowel [æ]: Table 3 shows that the effects of AGE ( $F(1,23)=18.37$ ,  $p<0.001$ ) and SEX ( $F(1,23)=20.44$ ,  $p<0.001$ ) on F1 of vowel [æ] are significant. Results reveal that F1 of [æ] is 85Hz smaller in adults than in teenagers. Results also show that F2 in teenagers is 81Hz more than that in adults. Regarding the effect of age, these results are in contrast with the results of the study by Torre and Barlow (2009), while they are in line with a study carried out by Hillenbrand et al (1995).

Vowel [o]: Table 3 shows that the AGE ( $F(1,23)=44.09$ ,  $p<0.001$ ) affect F1 of vowel [o]. A post hoc bonferroni test shows that F1 of vowel [o] in adults is 67 Hz less than that in teenagers. Investigating the effect of AGE ( $F(1,23)=17.44$ ,  $p<0.001$ ) on F2 of vowel [o] shows that F2 of young people

is 170 Hz higher than of adults. While the effect of sex is not significant but the results show that F2 of males is 67 Hz higher than that of females.

These results are in contrast with the results of a study by Hillenbrand et al., (1995). Regarding males, the results are in line with the results of a study by Torre and Barlow (2009); however these two studies are different regarding females.

Vowel [e]: Results of table 3 show that the effects of AGE ( $F(1,23)=79.62$ ,  $P<0.001$ ) and SEX ( $F(1,50)=9.52$ ,  $p<0.01$ ) on F1 of [e] are significant. A post hoc bonferroni test shows that F1 of vowel [e] in adults is 80.50 Hz less than that in teenagers and F1 of females is 37 Hz more than that in males. Also the effect of SEX ( $F(1,23)=6.62$ ,  $P<0.01$ ) on F2 of vowel [e] indicate that F2 of vowel [e] in teenagers is 171 Hz more than that in adults. These results are in line with the results of Torre and Barlow (2009) and Hillenbrand et al., (1995).

Vowel [u]: Table 3 reveals that the effect of AGE ( $F(23)=28.02$ ,  $p<0.01$ ) is significant on F1 of [u]. It shows that adults have 63 Hz lower F1 than teenagers and females have 15 Hz higher F1 than males. Also the effect of AGE ( $F(1, 23)=6.07$ ,  $p<0.01$ ) on F2 of this vowel is significant. Its effect is due to 78 Hz higher F2 in teenagers than that in adults.

The findings of this research show that adults have lower F2 and F1 than teenagers and F1 and F2 of females for vowels [i] and [u] are higher than males.

Table 3. The effect of age (adults & teenagers) and sex(male &female) on F1 and F2 for each vowel in women, men, boys and girls.

vowel		AGE	SEX
æ	F1	F=18.87**	F=20.44**
	F2	F=23.29**	ns
a	F1	16.13	14.38
	F2	39.55	ns
i	F1	F=16.13**	F=14.38**
	F2	F=7.63*	F=50.11**
e	F1	79.62	9.52
	F2	ns	6.62
o	F1	44.09**	ns

	F2	17.44	ns
u	F1	$F=28.63^{**}$	ns
	F2	$F=6.02^*$	ns

\*  $P<0.01$   
 \*\*  $P<0.001$

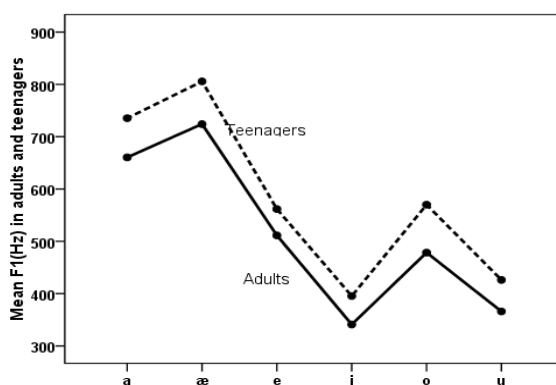


Figure 3. Mean F1(Hz) of vowels in adults and teenagers

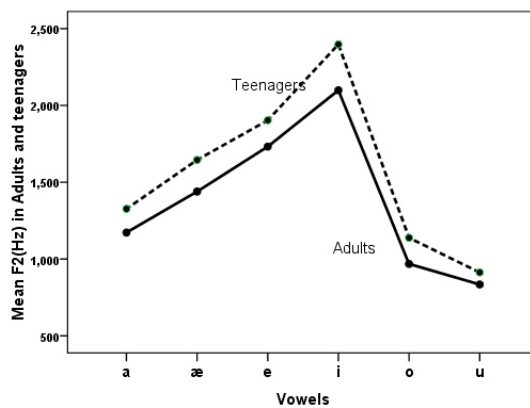


Figure 4. Mean F2(Hz) of vowels in adults and teenagers

### 4.3. Intensity

In the case of intensity, there was the main effect for SEX ( $F(1,19)=13.20$ ,  $p<0.001$ ). The effect of sex on intensity is due to 1.97dB higher intensity in males than that in females. The results show that vowels produced by men are more intense than those produced by women (see fig. 5).

Table 4. Mean intensity and Standard deviation (in parenthesis), in dB, for vowels.

Age			
adult	teenager	adult	teenager
81.46(2.5)	79.93(1.3)	81.82(1.1)	79.41(2.1)

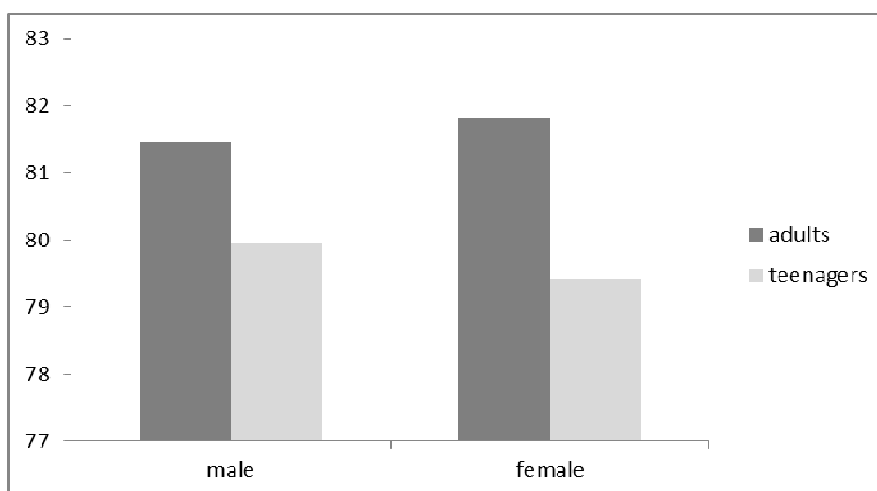


Figure 5. Mean intensity in different sex (males and females) and Age (adults vs teenagers).

### 4.4 F0 (fundamental frequency)

Table 6 shows that the effects of SEX ( $F(23)=111.26$ ,  $p<0.001$ ) and AGE ( $F(23)=5.79$ ,  $p<0.01$ ) on the fundamental frequency are significant.



Reviewing the results of bonferroni post hoc test revealed that F0 was 61 Hz less in adults than in young people and it was 13.10 Hz more in women than in men (Fig. 6 & 7).

Table 5. Mean F0 and standard deviation of F0 in Hz for vowels in men, women, boys and girls.

men	192.67(35)	boy	281.29(24)
women	232.87(20)	girl	267.40(20)

Table 6. The effect of age and sex on F0 of vowels

	AGE	SEX
F0	111.96**	5.79*
P<0.01*		
P<0.001**		

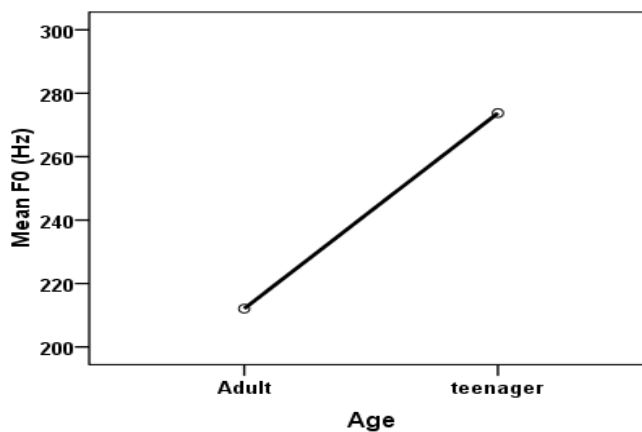


Figure 6. Mean F0 in adults and teenagers



Figure 7. Mean F0 in male and female

Comparing F0 in adults and young people shows that the effect of age is significant ( $F(1,23)=69.62, p<0.001$ ). Results of bonferroni post hoc test show that F0 does not increase with age; F0 was 88 Hz more in young people than that in old ones. Moreover, interaction of variables show that the interaction of AGE x SEX ( $F(1,23)=18.05, p<0.001$ ) is significant. Results of bonferroni post hoc test show that F0 of male adults is 41 Hz less than that of women, while it was 21 Hz more in boys than in girls. It shows that F0 increases with age in men, whereas it decreases with age in women.

Previous studies indicate that there was disagreement with respect to differences of F0 in men and women (Mueller, 1985, 1997; Mueller et al., 1984; Nishio & Niimi, 2008; Russell et al., 1995, Benjamin, 1981, 1982; Hollien & Shipp, 1972; Honjo & Isshiki, 1980; Mysak, 1959; Ramig et al., 2001). The results of this research is consistent with the prior finding reported by Torre and Barlow (2009) on F0 differences between men and women. They stated that F0 decreases in women but increases in men with age. Results of our study are in line with the results of the study carried out by Iseli et al. (2007). The results are also consistent with some other investigations showing a decrease in F0 and F1 with increasing age (Reubold et al., 2010; Linville, 1996; Linville and Fisher, 1985a & b).

## **5. Conclusion**

The results of this research show that properties of F0, Formants, Intensity and duration are related to age and sex. It is observed that F0 increases with age in men and decreases with age in women. This result is consistent with findings of previous researches ((Benjamin, 1981, 1982; Hollien & Shipp, 1972; Honjo & Isshiki, 1980; Mueller, 1985, 1997; Mueller et al., 1984; Mysak, 1959; Nishio & Niimi, 2008; Ramig et al., 2001; Russell et al., 1995). Moreover, the extent of age-related difference is light for women. We saw F1 of vowels [æ, a, e,] decreases with age, Whereas F1 of vowels [o,u] increases with age and F2 of vowels [I, u] in females is more than that in males. Also the results show that Adults produce more intense sounds than young people and men have higher intensity than women. As the results show young people and women have longer sounds than adults and men.

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