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Normative Data on the Speaking Fundamental Frequency Values of the Indian Bilingual Speakers: A Forensic Phonetic Study

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Abstract: ***The aim of the study is three-fold: 1) to obtain normative data on the speaking fundamental frequency (SFF) of Indian speakers, 2) to compare the SFF values of Indian speakers across seven different age groups (10-70 years) to see if any differences exist and 3) to explore if the language used (English and Telugu) has any effect on the SFF values. The study included 70 Indian speakers whose ages ranged from 10 to 70 years. The stimulus material comprised read passages and spontaneous speech samples in two languages (English and Telugu). The average SFF values were extracted using PRAAT software and the obtained values were compared across the different age groups chosen***.

Keywords: Speaking fundamental frequency, Indian bilingual speakers, Forensic Phonetics.

1. Introduction

In the recent past, the world has witnessed an unprecedented phenomenon of globalization. People crossing national borders and settling down in foreign countries for better livelihood has become the order of the day. Consequently, multi-ethnicity has become a norm more than an exception in many of the developed countries. This phenomenon has posed many challenges to the experts in the world of Forensic Phonetics.

Forensic Phonetics predominantly entails identifying the criminals based on their speech samples. In forensic speaker identification "an utterance from an unknown speaker has to be attributed, or not, to one of a population of known speakers for whom reference samples are available" (Nolan:1983).One of the aspects of Forensic Phonetics, Speaker Profiling (i.e. identifying the ethnicity, age, gender etc. based solely on the speech), has gained immense significance in the world of crime owing to the multi-ethnic backdrop. In other words, in the event of commission of a crime, the investigating agencies would benefit greatly if they can identify the ethnicity (in addition to other indexical markers) of the incriminating speech sample. This may eventually aid them in narrowing down their search for the perpetrator. Further, this knowledge may also assist in the Linguistic analysis of the determination of origin (LADO) in cases of refugees seeking asylum. Therefore, it is deemed essential to carry out research on the phonetic features (SFF being one of them) of different ethnicities.

2. Background Literature

There are several segmental and suprasegmental features of speech, which when analysed scientifically, aid in forensic speaker identification. In the area of Forensic Speaker Identification, it has been well established that the acoustic feature 'Pitch' (a perceptual correlate of fundamental frequency) is a good indicator of speaker's identity(Rose: 2002) and that the speaking fundamental frequency (SFF), which is a long-term average of fundamental frequency, is identified as a robust parameter in the speaker identification process(Nolan:1983). The following is a brief summary of the work that has been carried out on the pitch/SFF values of various ethnic groups in the world.

Natour & Wingate (2009)investigated the SFF values of Jordanian Arabic speakers and compared their SFF values with those of other ethnicities like Caucasian and African-American speakers. The study included 300 Jordanian Arabic speakers (100 adult males, 100 adult females) whose age ranged from 18 to 24 years. The study also included 100 children (50 boys and 50 girls) who were first graders. The speakers were asked to say their name in a carrier phrase like 'My name is …' and the average SFF values have been observed as 137.45 Hz (male speakers), 230.84 Hz (female speakers) and 278.04 Hz (children). When these values were compared with the SFF values drawn from other studies on Caucasian speakers, the SFF values of male and female speakers of Jordanian Arabic were similar. However, the children of Jordanian Arabic have exhibited higher SFF values than those of Caucasian children.

Quite an intriguing study on Japanese men and women was carried out by Nishio & Niimi (2008). The study revealed that the older women exhibited a noteworthy decrease in their SFF values. The study calculated the SFF values of 374 healthy Japanese speakers (187 male and 187 female). For ease of comparison, the speakers were divided into three age groups: young adults (19-34 years), middle aged (35-59 years) and old aged (above 60 years). The speakers were asked to read out 'The North Wind and the Sun' passage in Japanese. The study showed that the mean SFF values of male speakers were 121.83 Hz (young adults), 120.95 Hz (middle aged) and 127.82 Hz (old aged). Likewise, the average SFF values of female speakers were 224.58 Hz (young adults), 196.31Hz (middle aged) and 178.92 Hz of the aged women. Given below is a graphical representation of SFF values of Japanese male and female speakers across

different age groups.

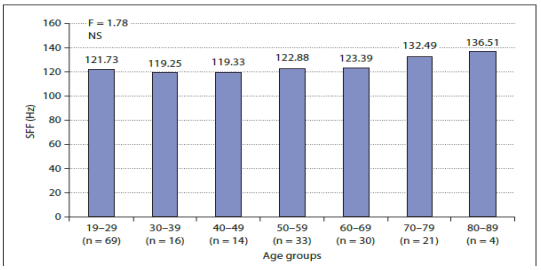

Figure 1: SFF Values: Japanese Male speakers

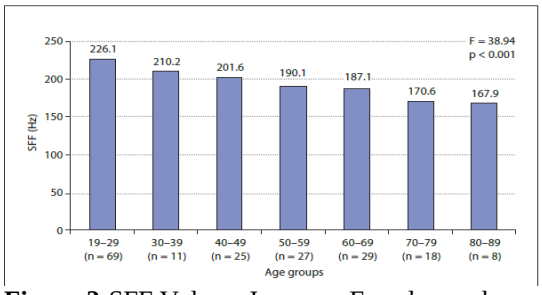

Figure 2:SFF Values: Japanese Female speakers

The results of this study showed that with the increase in age, there was moderate increase in the SFF values of men, however, a notable decrease was observed in the SFF values of female speakers.

A comprehensive summary of the SFF values of different age groups drawn from several widely accepted studies has been presented graphically by Baken (2004), which is reproduced below.

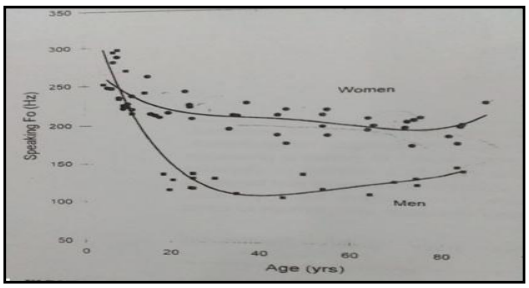

Figure 3:SFF values of different age groups drawn from various studies

Baken emphasizes that the SFF values are "by no means constant across the life span." He explains that "the human larynx is 'sexually dimorphic' and women generally exhibit a higher SFF than do men." He further describes that "the SFF values of both men and women tend to decrease with increasing maturity until, as age advances, the SFF actually rises again. The effect is greater and occurs at an earlier age in men than in women. Under neutral circumstances, the vocal folds of men and women vibrate more rapidly as age advances."

A rather substantial work on how human voice changes over life has been demonstrated by Hollien (2012) through male–female coalescence theory of aging. Based on many notable studies, Hollien has captured the changes in the F0 values of male and female speakers with the increase in age. Given below is a pictorial representation of male–female coalescence theory of aging.

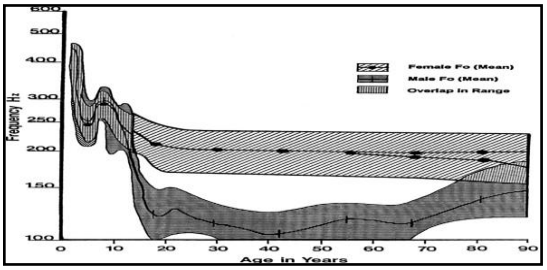

Figure 4: Male-Female Coalescence theory of Aging

The graph capturing the changes in the SFF values across different age groups clearly demonstrates the gender variation in the SFF values. While the SFF value curve was steady across age groups for female speakers (barring the overt dip during the adolescent phase), the male speakers, on the other hand, experienced drastic drop in the SFF values during the adolescent phase and a considerable rise in the last two decades.

One of the researches (Chatterjee et al.: 2011) carried out on Indian speakers studied the effect of age and gender on voice range profile (VRP). The study included 90 Bengali male and female speakers whose age ranged from 20-70 years. The speakers were grouped into three different age groups (20-30, 40-50 and 60-70). The study reported that there was a significant difference in the F0 values of male and female speakers. Female speakers of 60-70 years have exhibited slightly lower F0 values compared to younger women (20-30 and 40-50 years), whereas male speakers of 60-70 years have exhibited slightly higher F0 values than the young and middle-aged men.

Another preliminary investigation has been made by Sebastian et al. (2012) to study the effect of age-related changes on the parameters of voice in geriatric (60-80 years) male and female speakers. The study involved 40 (20 male and 20 female) normal geriatric speakers. The results of the study reported that there was no significant change observed in the acoustic parameters (F0) either in males or in female speakers across the age of 60 to 80 years.

On similar lines, Raj et al. (2009) examined the changes in the SFF values of Indian pre-menopausal and post-menopausal women. The study was carried out on 55 (35 pre-menopausal and 20 post-menopausal) Indian women speakers. The age of pre-menopausal women was identified as 20-30 years and that of postmenopausal women is 50 years. The SFF values of pre-menopausal women and post-menopausal women have been identified as 231.49 Hz and 204.98 Hz respectively. The study concluded that the SFF values of post-menopausal women were lower than the SFF values exhibited by pre-menopausal women.

3. The Present Study

It is noteworthy that, thus far, several attempts have been made in identifying the SFF values of different ethnicities in the world. When it comes to research on Indian speakers, studies investigating the F0 values have been carried out. However, there exists a serious dearth of research on the

speaking fundamental values (an established robust feature in speaker identification) of Indian speakers.

4. Aim

The aim of the study is three-fold: 1) to obtain normative data on the speaking fundamental frequency (SFF) of Indian bilingual speakers, 2) to compare the SFF values of Indian speakers across seven different age groups (10-70 years) to see if any differences exist and 3) to explore if the language used (English and Telugu) has any effect on the SFF values.

5. Methodology

The study included 70 Indian bilingual speakers (35 male and 35 female) whose ages ranged from 10 to 70 years. The subjects were categorized into 7 age groups (10, 11-20, 21-30, 31-40, 41-50, 51-60 & 61-70) for ease of comparison. All the speakers were native speakers of Telugu (a popular South-Indian Language) and were also proficient in English. It was ensured that none of the speakers had any speaking or hearing impairment.

Each speaker was asked to read out phonetically balanced passages, one in English (of 196 words in length) and another in Telugu (of 103 words in length). The subjects were also asked to talk spontaneously for a minute in each of the languages (Telugu and English) on a given topic. The two modes of speech served a binary purpose. While reading a controlled text provided with a homogenous data, spontaneous speech on the other hand, bore semblance to real-life forensic data.

Once the speech samples were recorded, the SFF values (of both the read and spontaneous speech samples in both the languages) were obtained for every ten seconds using PRAAT software and the average of those values has been calculated. The obtained SFF values were compared across the several age groups and languages chosen.

6. SFF Values of Indian Bilingual Speakers

Given below is a graph which gives the normative data on the SFF values of Indian male and female bilingual speakers. The SFF values shown in the graph are the averages of their read passage and spontaneous speech in two languages, English and Telugu.

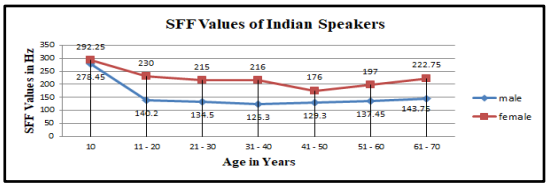

Figure 5: SFF values of Indian bilingual speakers

The graph demonstrates how the SFF values of Indian bilingual speakers vary over their lifespan. It may be observed that the SFF values of 10 year old children, both male and female, began at a similar point. However, with the onset of adolescence, the SFF values have lowered significantly in girls and drastically in boys.

The male speakers of 20 to 70 years have exhibited two distinct patterns: the speakers of 21 to 40 years have displayed a mild fall and the speakers of 41-70 years exhibited a mild upward shift in their SFF values.

On the other hand, the female speakers across 20-70 years have exhibited three different patterns: while the SFF values remained steady in the next two decades (21-40 years), it was interesting to observe that there has been a significant lowering of the SFF values during the menopausal age (41-50 years), which only reinstates the findings of research on menopausal age (Ex: Nishio & Niimi 2008) that the SFF values tend to decrease during this period. In the later years (50 to 70), however, the female speakers have exhibited a slight increase in their SFF values.

7. Effect of Language on the SFF Values

As the final objective is to find out whether the language used by the speakers has any bearing on the SFF values, the average SFF values obtained from English and Telugu speech samples drawn from both read and spontaneous speech have been compared. Since the SFF values differ drastically by gender, the male and female speakers have been analysed separately.

8. Comparison of the SFF values of Male speakers in English & Telugu

Given below is a graph which represents the SFF values of 10-70 years male speakers. It includes the average SFF values of English and Telugu (both read and spontaneous speech).

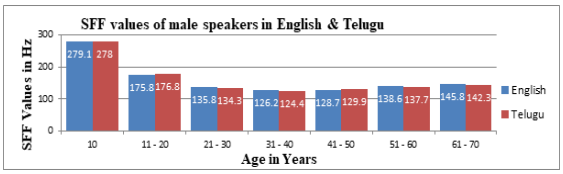

Figure 6: Comparison of the SFF values of male speakers in English & Telugu

The graph demonstrates that the male speakers (across all age groups) did not show any differences in the SFF values when the two languages, English and Telugu, were employed. It was evident from the results that there was no effect of language on the SFF values of male speakers.

9. Comparison of the SFF values of Female speakers in English & Telugu

A table which elucidates the SFF values of 10-70 years female speakers has been reproduced below. This table includes the average SFF values of English read and spontaneous speech and Telugu read and spontaneous speech.

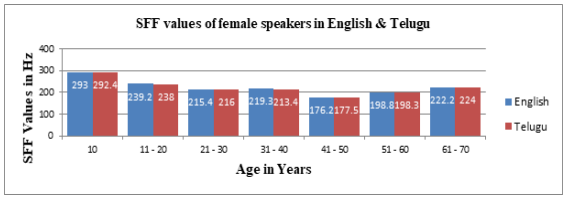

Figure 7: Comparison of the SFF values of female speakers in English & Telugu

A close look at the table reveals that irrespective of the age group, the female speakers exhibited no differences in the SFF values across the two languages employed.

10. Findings

The following is a summary of the conclusions drawn from the study.

- The normative data on the average SFF values of the Indian male bilingual speakers across different age groups is as follows: 10 years (278.4 Hz), 11-20 years (140.2 Hz), 21-30 years (134.5 Hz), 31-40 years (125.3 Hz) and 41-50 years (129.3 Hz), 51-60 years (137.4 Hz) and 61-70 years (143.7 Hz).
- The normative data on the average SFF values of the Indian female bilingual speakers across different age groups is as follows: 10 years (292.2 Hz), 11-20 years (230 Hz), 21-30 years (215 Hz), 31-40 years (216 Hz) and 41-50 years (176 Hz), 51-60 (197 Hz) and 61-70 years (222.7 Hz).
- The male speakers have exhibited three distinct SFF patterns across age groups. With the onset of adolescence, the speakers of 10 to 20 years have displayed a steep fall in the SFF values. As the age progressed from 20 to 40 years, a downward shift was observed followed by a mild upward shift from ages 41-70.
- The female speakers, on the other hand, have exhibited four distinct SFF patterns across the given age groups. Between the ages 10-20, there was a significant drop in the SFF values. However, it remained steady in the next two decades (21-40 years). It was interesting to observe that there has been a significant lowering of the SFF values during the menopausal age (40-50 years) and in the later years (50 to 70), however, the female speakers have exhibited a slight increase in their SFF values.
- Irrespective of the age group, the language used has no bearing on the SFF values of both the male and female speakers.

11. Forensic Significance

SFF is a key element in forensic speaker identification. The uniqueness of an individual is reflected through the pitch apart from many other aspects. Like many other physiological changes, vocal folds also undergo several changes with age, thereby exhibiting different SFF values across different age groups. Therefore, it is important to compare these changes across different age groups.

Also, it is a given that most of the Indian speakers are either bilinguals or multi-linguals. In this bilingual/multilingual context, it is likely that, in the commission of a crime, the perpetrator may shift from one language to the other, thereby making it important to know how language affects the SFF values.

The present study is a modest attempt to document the SFF values of Telugu-English bilingual speakers as it provides a database for speaker profiling in the field of forensic speaker identification in India.

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