ACOUSTIC ANALYSIS OF ENGLISH VOWEL SOUNDS PRODUCED BY SINDHI SPEAKERS

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Original Article

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Abstract

The present study examines the English vowel production of Sindhi speakers acoustically. This study spotlights Sindhi speakers from two geographical locations in Pakistan: Hyderabad and Islamabad. Despite sharing vowel types, there is disparity between English and Sindhi vowel sound articulation. The PRAAT software (Boersma & Weenink, 2019) was used to analyze English vowels' duration and quality produced by the speakers. For this, a monosyllabic wordlist for ten vowel sounds with CVC structure in 'hVd 'context within a carrier sentence was recorded from twenty-six Sindhi speakers.The findings of this study reveal that Sindhi speakers, in terms of vowel quality, lack the realization of clear contrast between the English vowel pairs. Whereas, English front vowels; /e/, /æ/, and /ɛ/ are almost produced similarly. All vowels were classified as short or long in terms of length but not enough contrast was found in all pairs of vowels except /iː/-/ɪ/. The findings of this study would help English language teachers to follow the acoustic-phonetic aspects of language while teaching pronunciation to second language learners and to develop artificial speech systems and speech recognizers based on Sindhi speakers' English use.

Keywords: Acoustic analysis, Formant frequency, PRAAT, Spectrogram, Vowel duration, Vowel quality

Introduction

There are many reasons to study speech acoustically in speech acoustics; the acoustic signals help in making the relations between speech production and speech perception. For this, the acoustic analyses provide information about the speaker's intent and listeners' perception of the produced acoustic signals. The advancements in computer science have made acoustic research easier relatively in terms of time and resources. The availability of numerous quantitative theories has made the analysis of acoustic data easier in terms of speech articulation and perception. The acoustic signals are the natural input for the studies of speech analyses. The theoretical knowledge and the use of technology have together opened new doors in the fields of acoustics. The acoustic data has the potential to help in conducting the research on speech

related issues. The acoustic data provide ways to deal by assessing and managing the language issues.

According to past researchers, Asian language speakers show phonetic inaccuracies (Flege, 1989; Pittman & Ingram, 1992). The extent of phonetic incorrectness in a second language is related to the length of exposure to a particular language in which L2 is realized (Johnson & Newport, 1991). The reasons for phonetic inaccuracies are the differences in the segmental and suprasegmental features of languages (Cheng, 1987; Os, 1985).

In this research, the vowel phonemes are analyzed acoustically by their spectrographic representation of formants and the duration. The formant frequencies and the duration that highlight the quality and the length of the vowel significantly make a better understanding of spoken language variety. These two characteristics are required to describe a vowel phoneme. The formant frequencies and the duration of vowels have been analyzed using PRAAT, open computer software.

Research Questions

The study answers the following questions:

1. What are the acoustics characteristics of Sindhi speakers' English vowel sounds?
2. How much do the duration and quality of the usual English vowel pairs as uttered by Sindhi speakers differ from one another?
3. What are acoustic characteristics of Sindhi speakers' English vowel sounds based on their geographical location?

Literature Review

Human speech has been investigated by language experts to describe various sounds that make up the language. The description of speech proves that there are different sound categories in human speech (Ladefoged & Madison, 1996). The language's phonemic inventory represents a set of spoken sounds. Traditionally, the phonemic inventory of a language is categorized into consonants and vowels, which are the segments of any sound and make up sound segments. These segments of sound are called phonemes-abstract sounds- comprised of consonants and vowels which occur in a particular sequence in a language.

Acoustic studies of vowels of different languages are based on multiple factors as some of the researchers explore the acoustic features of vowels of a language spoken by a certain group of people that can be based on their age, gender, geographical location, education, social class, and so on. The term demographic is basically related to the characteristics of different human groups, like their age, education, and income range. Studying demographic variables in acoustic studies of vowels and consonants has been the focus of many researchers (e.g., Adank et al., 2004; Perry et al., 2001). Demographic variables of different groups are different in nature.

The spectrogram is the visual representation of acoustic properties of sound generally, and speech sounds in particular. It represents the acoustic features i.e., frequency, time, and the formant frequencies that help in the study of speech sounds (Baart, 2010). The spectrograph is a graph or upper panel of the PRAAT window which shows the speech sound in the form of waves. These waves can help linguists and researchers to analyze the type of sound. The spectrogram is the representation of the vibration of air particles which is then reflected by waves in PRAAT.

Geographical location in acoustic studies is also as important as in sociolinguistic studies because people living in more advanced areas tend to speak language with more fascinated style as compared to the people who are living in remote areas (Trudgill & Watt, 2013). The current research also focused on geographical location of individuals that how people belonging to same language background can speak the language differently while living in different geographical location.

Pakistan is a country where more than seventy languages are spoken, and a single language is spoken in different areas, which results from minor or sometimes major changes in the language and the way of speaking the language. People belonging to certain groups have some traits, and these traits become the reason for change in a language like an educated individual will speak certain language in a better way than an uneducated one. Besides these demographic variables, there are other factors as well than might bring change in the way someone speaks the language like the influence of mother tongue (Muriungi & Mbui, 2013, Ringborm, 1987).

Sindhi shares its phonemic inventory with other Indo-Aryan languages. The Sindhi language has ten vowels in its phonemic inventory. The vowels of the Sindhi language are given below:

Table 1.1
Sindhi Vowel Inventory (Keerio, 2010)

S.No.	IPA Symbol	Features
1	**I**	high-front/close-front
2	**ɪ**	high-front/close-front short
3	**E**	mid-close front long
4	**ɛ**	mid-open front long
5	**ə**	open-central short
6	**ɑ**	open-back long
7	**O**	mid-close back long
8	**ɔ**	mid-open back long
9	**ʊ**	high-back/close-back short
10	**U**	high-back/close-back long

There have been several studies in past that were aimed at exploring the acoustic features of speech sounds. AsKeerio et al. (2014a) undertook an acoustic investigation of eleven Sindhi vowel sounds. The research measured the average fundamental frequency, the overall average of the 4 formants (F1 to F4), and the average vowel duration across all Sindhi dialects used in Sindh, Pakistan.

In another work, Keerioet al. (2014b) studied the acoustic analysis of phonemic consonants (liquids) of the Sindhi language in which all liquid consonants were analyzed when articulated within sentences as well as isolated word utterances. The study was based on three parameters: a waveform, the spectrogram, and the formant tracks. These parameters are fundamental focus to studying speech sound with the acoustic lens.

Research Methodology

This acoustic study has been conducted according to the methods established by former researchers in vowel studies like ElGhouati et al. (2018) and Phon (2017) defy the effect of demographical factors on English language learning based on the findings of Moroccan university and the Cambodian university students' English proficiency respectively. El-Omari (2016) studied secondary school students in Jordan and found an effect of social aspects on the English language learning of students.

This research analyses the English vowels' pronunciation in Sindhi speakers' speech using acoustics analysis. This study assessed data collected from speakers of the Sindhi language based on the geographical location to give an answer to the questions of this research. The acoustic analysis of the acquired data caused the account of the English vowel sounds spoken by Sindhi speakers. This study is descriptive in nature. The quantitative approach is adopted to analyze the acoustic data using an acoustic software version (6.1.04) of PRAAT (Boersma & Weenink, 2019).

The data was recorded from 40 participants. The researcher first traveled to Hyderabad, his native place, to obtain speech recordings from participants related to different fields of life, keeping in view the study objectives. Then about half of the total participants' data was collected from Sindhi speakers in Islamabad who have been living there for 4-10 years for various reasons. The speech samples of the participants were collected at different places based on their availability. Out of 40, 26 participants' recordings were considered for the study. The reason to reduce the participants' recordings is that there were so many external voices in their recordings which is not suitable for acoustic considerations. That is why such recordings were discarded from the study.

The criterion for the selection of respondents of the study was to consider their mobility. All participants had 15-20 yearsof exposure to English language as a medium in their academic careers. All participants' native language was Sindhi, with no kind of speech disorders. The minimum educational level was Intermediate (12 years), and the maximum was Master (16 years) from different fields of study. The equal split was made in the number of participants from Hyderabad and Islamabad with varying numbers in mobility and educational level based on the availability of the participants.

Data Analysis

The demographic details of the Sindhi speakers are given in Table 1.2.

Table 1.2
Demographic details of the Participants

Speakers	Geographical Location
S A	Hyderabad
S B	Hyderabad
S C	Hyderabad
S D	Hyderabad
S E	Hyderabad
S F	Hyderabad

S G	Hyderabad
S H	Hyderabad
S I	Hyderabad
S J	Hyderabad
S K	Hyderabad
S L	Hyderabad
S M	Hyderabad
S N	Islamabad
S O	Islamabad
S P	Islamabad
S Q	Islamabad
S R	Islamabad
SS	Islamabad
S T	Islamabad
S U	Islamabad
S V	Islamabad
S W	Islamabad
S X	Islamabad
S Y	Islamabad
S Z	Islamabad

*S=Speaker
*A-Z: Participants

A speech sample utilized in this current research was ten monosyllabic words list in the hVd context. These vowels include /iː/, /ɪ/, /e/, /ɛ/, /æ/, /ʌ/, /uː/, /ʊ/, /ɔː/, /ɑː/. The structure of the words was restricted to CVC, in which these vowels occur. However, the word list containing these vowels was recorded in a carrier sentence. The carrier sentence was as follows;

I can say<u>hVd</u> again

As the structure used for the words containing vowels (hVd) minimizes the effect of preceding and following consonants, therefore the vowel onset and offset can be viewed on the PRAAT spectrogram along with the waveforms and the dark frequency bands, as shown in figure 1.1.

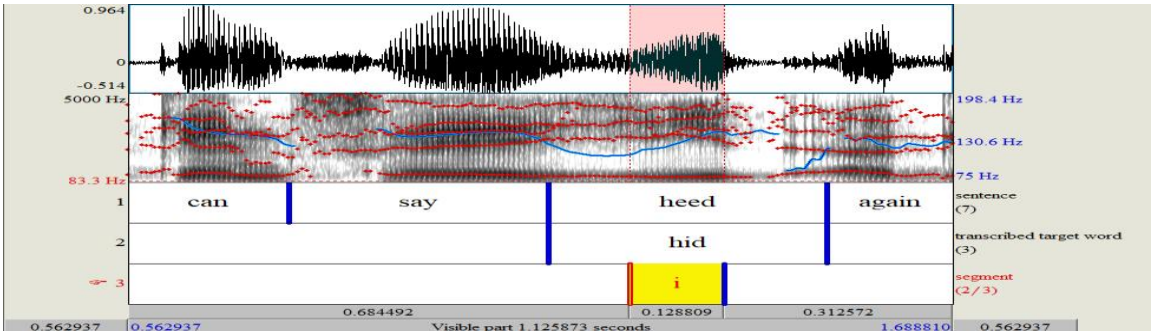

Figure 1.1: Spectrographic representation of vowel /iː/

The table 1.3 contains the words which were selected for the measurement and analysis of formant frequencies and the vowel duration of Sindhi speakers.

Table 1.3
Word list containing Vowel sounds in hVd context.

Vowel	Word
/iː/	Heed
/ɪ/	Hid
/e/	Hayed
/ɛ/	Head
/æ/	Had
/ʌ/	Hud
/uː/	Who'd
/ʊ/	Hood
/ɔː/	Hawed
/ɑː/	Hod

The average values of the frequencies of formant and the duration of the vowel of the speakers within the target word *hVd* in the carrier sentence are given in the Tabular form based on demographic variable i.e., geographical location. The vowel sounds produced by the speakers were converted into Bark scale to plot in vowel frequency (F1 and F2) charts.

Table 1.4
Mean Formant Frequencies (F1 and F2) based on speakers' mobility extracted from target word within the carrier sentence

Vowel	Geographical Location A		Geographical Location B	
	F1 (Hz)	F2 (Hz)	F1 (Hz)	F2 (Hz)
iː	387	2467	301	2313
ɪ	441	2256	416	2257
E	638	2070	485	2159
E	571	2175	521	2075
Æ	599	2090	537	2082
ʌ	502	1288	431	1299
uː	460	1063	411	1209
ʊ	480	1124	374	1164
ɔː	775	1364	679	1338
ɑː	554	1210	473	1194

* Geographical Location A= Hyderabad, Geographical Location B= Islamabad

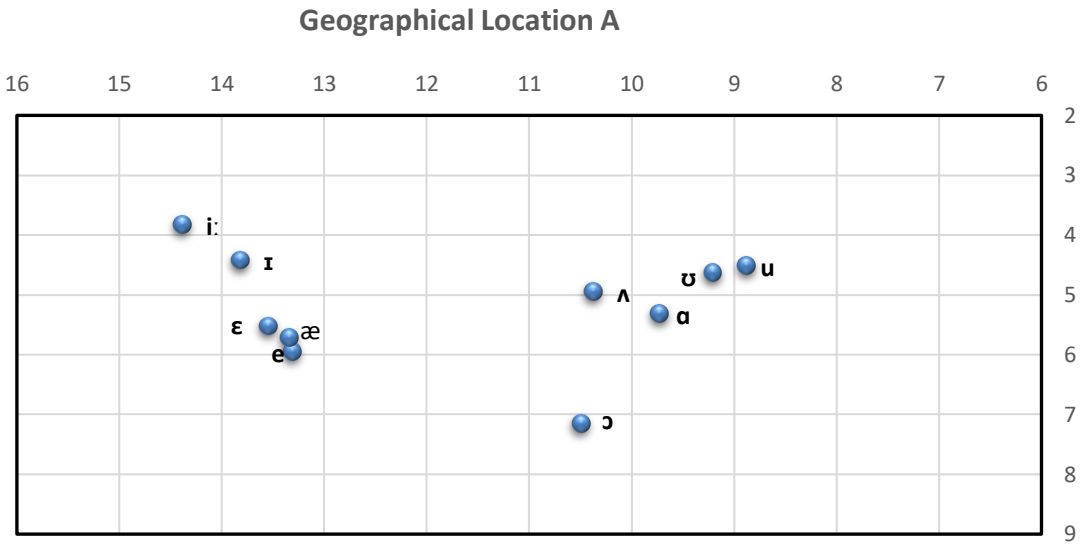

Figure 1.2*:* Average speakers' formant plot from Geographical Location A (Hyderabad)

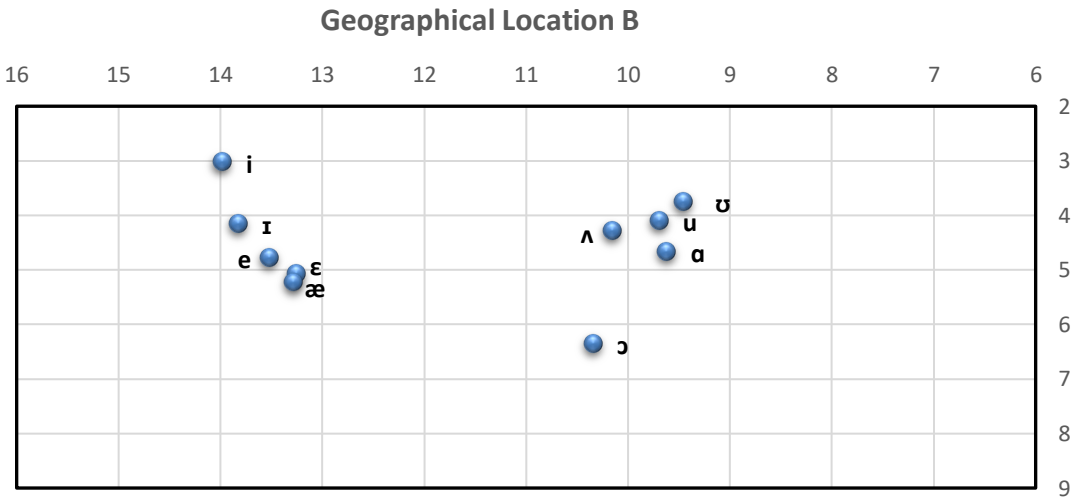

Figure 1.3*:* Average speakers' formant plot from Geographical Location B (Islamabad)

Formant Frequencies

As reflected in the formant plots in Figure 1.2 and 1.3, there was contrast seen between front vowels /iː, -ɪ/ for the speakers of both the locations (Hyderabad=A, Islamabad=B) where vowel /iː/ was produced higher for A Speakers and also less fronted than for B Speakers The front-mid vowels /e/- /ɛ/ were produced very close to one another for speakers of both the locations whereas vowel /æ/ lacked contrast to vowel /ɛ/ for speakers A and were realized with almost same. But the vowel /ɛ/ and vowel /æ/ were produced slightly higher than vowel e/ for speakers A. Collectively, the vowels /e/- /ɛ/- /æ/ produced by B speakers were higher than the speakers A.

The high back vowels /uː/-/ʊ/ did contrast for both A and B but the vowel /ʊ/ was produced bit higher than long vowel /uː**/** for B speakers. Whereas, both the vowels /uː/-/ʊ/ for A speakers were produced low as compared to B speakers. The vowels /ʌ/- /ɑː/ contrast for both A and B speakers but the distance for B speakers is closer than A speakers and were produced little more central to than B speakers. A vowel / ɔː/ for A participants were produced at the same place as for B speakers, but it was lower in the vowel plot of A speakers than that of B speakers. Therefore, the formant plot generated out of F1 and F2 values of produced vowel sounds indicated that the vowel space for A speakers compared to the B speakers, appeared to have more open vowel space.

Vowel Quality Contrast

In order to see clearly how much vowel difference there is between the average English vowel pairs spoken by Sindhi speakers depending on where they are from (mobility). Their realization results for both short and long vowel pairs are shown. The F1 and F2 mean values for every common vowel pair for each speakers group based on their location were tested using the paired sample t-test. As seen in the scatter plots of two geographical locations of Sindhi speakers in Figure 1.2 and 1.3, both the group of speakers show a clear contrast in the realization of vowel pair /iː, -ɪ/. However, group B's average F2 values differ significantly from group A's on the basis of the t-test findings for F1 & F2 overall average for the pairs of vowel (t (12) = 0.47, p 0.05). The F1 and F2 values for the vowel pair /i/-/ for both groups of geographic location are summarized in Table 1.5.

Table 1.5

The result of t-test for the values of F1 and F2 of vowel pair /iː - ɪ/ based on Geographical Location

	Geographical location A		**Geographical location B**	
	F1	**F2**	**F1**	**F2**
df	12	12	12	12
t	-2.23*	2.80*	-5.20*	.47**

*p > 0.05; **p< 0.05

The realization of front vowel pair /e - æ/ for two groups of geographical location as seen in figure 1.2 and A and group B realize these vowels with a slight contrast. However, the results of t-test for the average values of F1 and F2 for the vowel pair for two groups of geographical location show no significant difference as summarized in Table 1.6.

Table 1.6

The result of t-test for the values of F1 and F2 of vowel pair /æ - e/ based on Geographical Location

	Geographical location A		**Geographical location B**	
	F1	**F2**	**F1**	**F2**
Df	12	12	12	12
T	-1.581*	.448*	1.824*	-1.318*

*p > 0.05; **p< 0.05

The back vowel pair /ɑː - ʌ/ realized by the speakers of two groups of geographical location as seen in scatter plots in Figures 1.2 and 1.3, indicates the contrast in their realization of the vowel pair. However, to verify the vowel pair contrast by both groups of speakers, t-test was prepared for the average values of F1 and F2 of the pair of vowels for both groups, the results show no significant difference as given in Table 1.7.

Table 1.7

The result of t-test for the values of F1 and F2 of vowel pair /ɑː- ʌ / based on Geographical Location

	Geographical location A		**Geographical location B**	
	F1	**F2**	**F1**	**F2**
Df	12	12	12	12
T	1.172*	-1.423*	1.927*	-1.435*

*p > 0.05; **p< 0.05

The two groups of speakers based on geographical location, in their realization of vowel pair / uː/-/ ʊ/ as seen in Figure 1.2 and 1.3, show contrast in the vowel pair realization for the speakers of both the geographical locations. However, the results of the t-test performed for the F1 and F2 mean values of the two groups for the pair of vowel / u/-/ʊ/ demonstrate that group A speakers had significantly lower average values of F2 ($t(12) = -2.12$, $p < 0.05$). As opposed to this, group B speakers' F1 average values differ significantly ($t(12) = 3.12$, $p < 0.05$). Hence, Table 1.8 summarizes the results of t-test for F1 and F2 values of vowel pair /uː - ʊ/ realization by the speakers based on their geographical location.

Table 1.8

t-test result for F1 and F2 values vowel pair / uː - ʊ/ based on Geographical Location

	Geographical location A		**Geographical location B**	
	F1	**F2**	**F1**	**F2**
Df	12	12	12	12
T	-1.097**	-2.116*	3.116*	.581**

*p > 0.05; **p< 0.05

Vowels Duration (Length) Contrast

The results of the duration of the articulated vowels for Sindh speakers at Hyderabad (A) and Islamabad (B) are reported here. The duration (length) of each vowel was extracted from the target word with *hVd* context in the carrier sentence articulated by the Sindhi speakers from Hyderabad and Islamabad. Their mean vowel duration values of the English front and back monophthong vowels measured in milliseconds (ms) are presented in Table 1.9.

Table 1.9

Mean Vowel Duration based on Sindhi Speakers' Geographical Location

Vowel	Geographical location A Vowel Duration (ms)	Geographical location B Vowel Duration (ms)
iː	144	154
ɪ	90	95
E	158	148
E	141	132
Æ	133	141
ʌ	147	100
uː	132	151
ʊ	122	125
ɔː	147	169
ɑː	103	115

As shown in Table 4.26, the Sindhi speakers from Hyderabad and Islamabad differentiate in the length realization of vowel /iː/-/ɪ/ where for Hyderabad speakers, the mean duration for vowel /iː/ is 144ms and for vowel /ɪ/ is 90ms, and for Islamabad speakers, the mean duration for vowel /iː/ is 154ms and 95ms for vowel /ɪ/. In the durational realization of vowel /e/-/ æ/ both the location speakers were observed with marginal variation in their vowel duration which is 158ms for /e/ and 133ms for /æ/ for Hyderabad speakers, and 148ms for vowel /e/ and 141ms for vowel /æ/ for Islamabad speakers. Moreover, both the location speakers seem to slightly differentiate in the realization of vowel /ʌ/- /ɑː/ where mean duration for Hyderabad speakers is 147ms for /ʌ / and 103ms for /ɑː/ and for Islamabad speakers 141ms and 115ms respectively. The mean duration values for the back vowels /uː/-/ʊ/ show that there is not noticeable contrast in the length of both vowels for both location speakers. Whereas speakers of Hyderabad lack in the realization of vowel duration contrast between vowel /ɛ/ and / ɔː/ but the speakers of Islamabad make slight contrast in the durational realization of two vowels which is 132ms for /ɛ/ and 169ms for /ɔː/.

However, pairs sample t-test statistical analysis was used to identify the important differences between the short and long vowel pairs in their duration for speakers of geographical location A and B. The results were found that the speakers of geographical location A and B show a significant difference in the length contrast for vowel pair /iː/-/ɪ/ (*t (12) = 4.69, p < 0.05), t (12) = 5.68, p < 0.05*). In addition, the speakers of geographical location A maintain length contrast for vowel pair /æ - e/ (*t (12) = -2.46, p < 0.05*). It was observed that in the realization of vowel pair /ɑː - ʌ / and /uː - ʊ/, both the groups of geographical location A and B speakers didn't make difference in the length of the pairs of the vowel. The outcomes for all short and long vowel pairs for the speakers of both the geographical location are presented in Table 1.10.

Table 1.10

t-test results for duration of vowels pairs based on Geographical Location

Geographical location	t-test values for /i: - ɪ/	t-test values for /æ - e/	t-test values for /ɑ: - ʌ /	t-test values for / u: - ʊ/
A	4.692*	-2.459*	-.913**	.703**
B	5.684*	-1.033**	.301**	1.158**

*p > 0.05; **p< 0.05

Conclusively, the analysis of data shows that the acoustic characteristics, the formants, and the duration of English vowel sounds spoken by Sindhi speakers were analyzed for the length and the quality of the vowels based on the geographical location of the speakers. The feature that was common to the Sindhi speakers' English vowel production is the lack of contrast in the realization of mid front vowels of English i.e., /æ /-, /e/ and /ɛ/, therefore realize these vowels with negligible difference that results in the realization of similar words although intend different words with vowel variation in them. The duration of the English vowels produced by Sindhi speakers is found not contrastive as they produced long and short vowels with varying duration interchangeably which is contrary to the English where, length is the contrastive feature of the vowel sounds.

Conclusion and Discussion

This research study explores the English vowel sounds' acoustic features of spoken by Sindhi speakers based on geographical location, with the objectives of examining the quality and the length of the typical pairs of vowels. The data obtained from this study was used to compare the groups of speakers for demographic variable (geographical location) separately for their English vowel production in terms of the quality and the length of the vowel sounds.

The size and shape of the vocal tract affects the clarity of the sounds of vowels and their understandability. Acoustically, in this study, the English vowels produced by Sindhi speakers are referred by bark transformed formant plots of the Sindhi speakers' vowel articulation as auditory perception. Knowingly, one of the factors for intelligibility properties of vowel sounds is related to the vowel space based on F1 and F2 plotting in the vowel plots (Kerio, 2010).

On the other hand, by observing the formant plots of Sindhi speakers' English vowel production and the results of t-test confirm that Sindhi speakers lack difference in the production of typical front vowel pair /e/, /æ/ and the vowel /ɛ/ therefore, realize all three vowels in similar manner. Consequently, the English words *hayed-head-had* been realized without much variation and can be perceived as same. This concludes that Sindhi speakers in their English use may cause difficulty for listeners to get the intended word realization which differ in /e/, /æ/ and /ɛ/ vowels in them.

In addition, the measured formant values of F1 & F2 which correspond a height and length of a tongue in the vowel production respectively showed that female speakers produce English vowel comparatively low in height and more fronted in length of the tongue than the male speakers. Further, Sindhi speakers produced high back vowel /u:/ and its short variant /ʊ/ with approximately similar in their values of F1 and F2 which resulted in the merger of a vowel pair /u:/-/ʊ/ in the formant plots of both Sindhi male and female speakers.

Also, the back vowel /ɔː/ was produced lowest by Sindhi speakers in terms of its height whereas lowest English back vowel pair / is produced close to high back vowel pair /uː/-/ʊ/. This confirms Sindhi speakers' pronunciation is different of the words which contain vowel /ɑː/, /ʌ/ and /ɔː/ than the native speakers.

In terms of typical English vowel pair quality contrast, Sindhi speakers do not show a categorical quality contrast in their production of English vowels. Therefore, the t-test results confirm that only high front vowel pair /iː/-/ɪ/ is contrasted that only by male Sindhi speakers with difference in their F1 and F2 values. Whereas female speakers produced both vowels with same length of the tongue based on their F2 values, but they significantly differ in vowel height in their production of the vowel pair. All other vowel pairs: /e/ -/æ/, /ɑː/, /ʌ/ and /uː/-/ʊ/ were not contrasted by the Sindhi speakers for F1 and F2 differences in their realization as confirmed by t-test results.

In terms of duration, Sindhi speakers do not differentiate in the production of typical English vowel pairs except the high front vowel pair /iː/-/ɪ/. Whereas the t-test results confirmed that only Sindhi male speakers produce /iː - ɪ/, /æ - e/, / uː - ʊ/ vowel pairs with duration contrast but interestingly Sindhi speakers produce long vowel /æ/ shorter than the short vowel /e/ in the vowel pair duration contrast.

Based on the geographical location, the speakers from *Geographical Location 1 (Hyderabad)* showed contrast only for F1 in the realization of vowel pair /uː/-/ʊ/ all other vowel pairs were realized with no significant contrast for their F1 and F2 value. Whereas the speakers of *Geographical Location2 (Islamabad)* showed contrast only in the F2 values for vowel pair /iː - ɪ / and / uː/-/ʊ/. In terms of vowel duration, the Sindhi speakers of the geographical location showed lack of length contrast in the vowel pair /iː - ɪ/.

The current study provides sufficient knowledge to conduct acoustic phonetic analysis of vowel phonemes with reference to the quality and the length of the vowels. This study is limited to two dimensional characteristics; F1 and F2, the acoustic correlates of the height and the degree of frontness and backness of the vowels to analyze them. The future researchers can include more dimensions; F3, F4 and so on to study other features of vowel phonemes involved in the holistic description of vowel-specific as well as speaker-specific information. Moreover, the study explores the English vowel sounds'production of by Sindhi participants/speakers. Therefore, the diphthongs and the triphthongs of English can also be explored in the speech of Sindhi speakers to get more information about the Sindhi speakers English vowel production. Furthermore, the factors involved in the variation of the vowels' production can also be explored in English language use of Sindhi speakers.

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