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Regional and Gender-Based Acoustic Variation in Pakistani English Vowels: A Sociophonetic Analysis of Thirteen Urban and Peripheral Varieties

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Abstract

This study investigates regional and gender-based variation in Pakistani English (PakE) vowel production using a multi-city corpus of 208 university speakers (104 female, 104 male) from thirteen Pakistani cities. Participants produced controlled word lists and semi-natural reading passages; recordings were aligned with the Montreal Forced Aligner (McAuliffe et al., 2017) and manually corrected in Praat for segmentation (Boersma & Weenink, 2023). Acoustic measures (F1, F2, duration) were extracted, z-score normalized (Adank et al., 2004), and analyzed with descriptive statistics, vowel plots, and inferential tests (ANOVAs with Tukey HSD and targeted pairwise comparisons). Results reveal a generally triangular vowel space subject to regional restructuring: front and central vowels (e.g., /æ, ɪ, e, ə, eɪ, əʊ/) show the widest regional dispersion in F2, while low/back vowels (e.g., /aːr, ɒ, ɔː/) show the largest regional differences in F1. Cross-regional patterns indicate marked centralization in several peripheral varieties and /uː/ fronting and low-vowel lowering consistent with substrate influence from Urdu, Punjabi, Pashto, and related languages. Urban centres (Karachi, Lahore, Islamabad) present more standardized, globally aligned vowel systems, whereas peripheral sites (e.g., Gilgit, Skardu, Quetta, Khuzdar) are more centralized. Gender strongly conditions these patterns: females occupy a larger vowel area (quadrilateral ≈ 4.505 z-units²) and exhibit broader dispersion across regions, while males show a compressed vowel space (≈ 2.538 z-units²). Interpreting these findings through Vowel Dispersion Theory, Schneider's Dynamic Model, and variationist gender theory, the data suggest female-led articulatory expansion and regionally patterned contact effects driving PakE's internal differentiation. The results have clear implications for theories of contact-induced change and for applied domains (speech technology, teaching), calling for region- and gender-aware modeling of PakE.

Key Words: Pakistani English, Regional Vocalic Variation, Gender Vocalic Variation MFA, PRAAT , Vowel Dispersion Theory (VDT)

1. Introduction

English in Pakistan occupies a unique sociolinguistic position as a co-official

language, a medium of higher education, and a marker of social prestige. Within this context, Pakistani English (PakE) has emerged as a distinct variety shaped by contact with regional languages such as Punjabi, Sindhi, Pashto, Balochi, and Urdu. While lexical and syntactic features of PakE have been described, its phonetic and phonological properties—particularly vowel production—remain underexplored. This gap is significant, as vowels are among the most variable and socially indexical features in world Englishes.

Vowel realizations in postcolonial Englishes often diverge from Inner Circle norms due to substrate influence, sociolinguistic identity, and contact dynamics. In PakE, regional diversity and gender further condition variation: speakers transfer phonetic patterns from their first languages, while female and male speakers may employ different strategies of vowel articulation, reflecting both global sociophonetic trends and local prestige orientations. Acoustic phonetic analysis, which quantifies vowel quality through formants (F1, F2) and duration, provides a rigorous means of identifying these patterns and positioning PakE within the wider landscape of World Englishes.

The present study investigates the acoustic properties of monophthongal vowels in PakE across thirteen cities, addressing three interrelated dimensions: (i) regional variation, (ii) gender-based differences, and (iii) substrate influence from local languages. The analysis is framed by Vowel Dispersion Theory, Variationist Sociophonetics, and Schneider's Dynamic Model of Postcolonial Englishes, with the aim of documenting PakE as a contact-driven yet systematizing variety undergoing nativization.

2. Literature Review

Research on the sociophonetics of World Englishes highlights how local ecologies, multilingualism, and contact dynamics shape postcolonial English varieties (Kachru, 1985; Schneider, 2007). Pakistani English (PakE), historically rooted in British colonial education and shaped by Urdu as a lingua franca, has developed distinctive segmental and suprasegmental features but remains underexplored compared to other South Asian Englishes (Rahman, 1990, 1991; Mahboob, 2003; Baumgardner, 1993). Given Pakistan's linguistic diversity—over 70 regional languages including Punjabi,

Pashto, Sindhi, Balochi, and Saraiki—PakE offers a valuable site for examining contact-driven phonological variation.

Studies of South Asian Englishes describe reduced vowel inventories, centralization, and limited diphthongization (Wells, 1982; Sailaja, 2009), features linked to substrate influence from L1s with fewer contrasts. Yet few large-scale acoustic studies have examined vowel systems across Pakistan's regions. Existing work suggests regional centralization and L1 transfer effects (Rahman, 1991; Khan, 2020; Ali & Qureshi, 2022), but most studies are small-scale and impressionistic.

Global research on vowel systems provides useful theoretical grounding. Vowel Dispersion Theory (VDT) posits that inventories evolve to maximize perceptual contrast (Schwartz et al., 1997). Dialect studies document systematic vowel shifts such as the Northern Cities Shift, low-back mergers, and /uː/-fronting in North America, Australia, and Britain (Labov, Ash, & Boberg, 2006; Cox, 2006; Harrington, Kleber, & Reubold, 2008; Thomas, 2001). In multilingual ecologies such as Singapore and African Englishes, substrate influence leads to vowel reduction and centralization (Deterding, 2007; Mesthrie & Bhatt, 2008), patterns resonant with PakE. Gender-based variation is another central factor. Acoustic studies show women typically produce higher formants, expanded vowel spaces, and greater hyperarticulation, often associated with clarity and prestige (Henton, 1995; Simpson, 2009). Labov's (1990, 2001) "gender paradox" positions women as both leaders of sound change and preservers of overt prestige. Studies in North America and Australia confirm women's role in vowel fronting, particularly /uː/-fronting (Clarke, Elms, & Youssef, 1995; Harrington et al., 2008). These findings suggest that female Pakistani speakers, especially in urban contexts, may similarly lead innovative vowel shifts.

Pakistani studies, though limited, consistently indicate regional and gendered variation. Early descriptions (Rahman, 1990, 1991; Baumgardner, 1993) noted centralization and reduced diphthongization, while Mahboob (2003) argued for an emerging Pakistani standard English influenced by British norms but increasingly localized. More recent work (Khan, 2020; Ali & Qureshi, 2022) links vowel fronting and raising to Urdu–Punjabi contact, though such studies rely on small samples.

The present study builds on this foundation by providing the first large-scale acoustic

analysis of monophthongal vowels in PakE across thirteen cities. By integrating Vowel Dispersion Theory (Schwartz et al., 1997), Variationist Sociophonetics (Labov, 2001), and Schneider's (2007) Dynamic Model, it demonstrates how regional L1s, gendered articulation, and sociolinguistic prestige norms interact to shape PakE vowels, positioning this variety as a contact-driven yet systematizing English within the World Englishes framework.

Table 1: ***Comparative Summary of Key Studies***

Scope	Study	Focus	Key Findings
Global – English Dialects	Labov, Ash, & Boberg (2006)	North American English	Northern Cities Shift; low-back mergers; regional chain shifts
	Thomas (2001)	New World Englishes	Acoustic mapping of regional vowel systems; systematic variation
	Cox (2006)	Australian English	/hVd/ vowel shifts; /u:/-fronting trend
	Harrington et al. (2008)	British English	/u:/-fronting linked to coarticulation and sound change
	Deterding (2007); Mesthrie & Bhatt (2008)	Singapore & African Englishes	Substrate influence causes centralization and inventory reduction
	Schwartz et al. (1997)	Vowel Dispersion Theory	Vowels distributed to maximize perceptual distinctiveness
Global – Gender	Henton (1995); Simpson (2009)	Male vs. female vowel spaces	Women show higher F1/F2, expanded spaces, hyperarticulation
	Labov (1990, 2001)	Gender & change	Women lead sound change; gender paradox
Pakistan	Rahman (1990, 1991)	Early PakE descriptions	Segmental variation; British influence; L1 transfer

	Mahboob (2003); Baumgardner (1993)	Sociolinguistic overview	Reduced diphthongization; urban standard emerging
	Khan (2020); Ali & Qureshi (2022)	Regional variation	Urdu–Punjabi influence; vowel centralization; limited datasets
This Study	Yaqub (2025)	13 cities, 13 varieties	Large-scale F1/F2 analysis; gender hyperarticulation; regional fronting/centralization

2.1 Theoretical Framework

This study integrates sociolinguistic, phonological, and sociophonetic perspectives to account for vowel variation in Pakistani English (PakE). Within Schneider's Dynamic Model of Postcolonial Englishes (2007), PakE is located in the Outer Circle (Kachru, 1985), at a stage of nativization where local languages shape its phonology. This ecological orientation emphasizes contact and identity as drivers of variation.

Phonologically, Feature Geometry (Clements & Hume, 1995) links formant values to contrastive features: F1 indexes vowel height, while F2 corresponds to backness. The Contrastive Analysis Hypothesis (Lado, 1957) explains how transfer from Urdu, Punjabi, Pashto, and Sindhi contributes to regionalized vowel qualities and centralization.

From an acoustic perspective, Vowel Dispersion Theory (Schwartz et al., 1997) frames vowel organization as a system-level optimization of perceptual contrast. Thus, fronting, lowering, and centralization in PakE reflect both contact effects and perceptual restructuring within multilingual settings.

Finally, variationist sociophonetics (Labov, 1972, 1994) and gender studies (Labov, 1990, 2001; Henton, 1995; Simpson, 2009) demonstrate that women typically expand vowel spaces and lead innovation, while men show centralization and conservatism. In PakE, these gendered patterns intersect with regional ecologies, reinforcing social meaning and structural change.

Together, these frameworks conceptualize PakE vowel variation as the product of historical trajectory, structural constraints, perceptual optimization, and sociolinguistic identity, situating it within both World Englishes theory and global

sociophonetic trends.

3. Methodology

Speech data were collected from 208 Pakistani English speakers (104 female, 104 male) representing 13 cities: Karachi (KHI), Abbottabad (ABT), Lahore (LHR), Islamabad (ISB), Multan (MUL), Muzaffarabad (MZB), Peshawar (PSH), Quetta (QUE), Skardu (SKD), Sakkar (SKR), Gilgit (GLT), Khuzdar (KHD), and Mirpur (MRP). Participants were 20–25 years old, university students (Yaqub, 2025).

A wordlist of monosyllabic words containing stressed English vowels, one rhotic vowel and two diphthongs were selected for the study. Recordings were conducted in quiet settings using a Zoom H5 recorder with a Shure SM58 microphone at 44.1 kHz (Yaqub, 2025).

The Montreal Forced Aligner was originally used to align recordings to words and phonemes (McAuliffe et al., 2017). Checks and refinements to Praat were made (Boersma and Weenink, 2023). Segments of the vowel were addressed with respect to the display of the waveform and the spectrogram. F1 and F2 frequencies of the first and second formant were observed at the middle of a vowel and the duration considered was the time taken between the start and end of the segment. Normalization To reduce the white-to-black see-variation with anatomical differences between speakers, each had formant values normalized by use of z-scores (Adank et al., 2004).

Exploratory visualization included descriptive statistics and vowel space plots by region and gender. Inferential analysis employed two-way ANOVAs with Vowel and City as fixed factors and F1.z, F2.z, and Duration as dependent variables. Post-hoc Tukey HSD tests identified significant pairwise contrasts. All analyses were performed in R (R Core Team, 2023) using tidyverse, emmeans, and ggplot2.

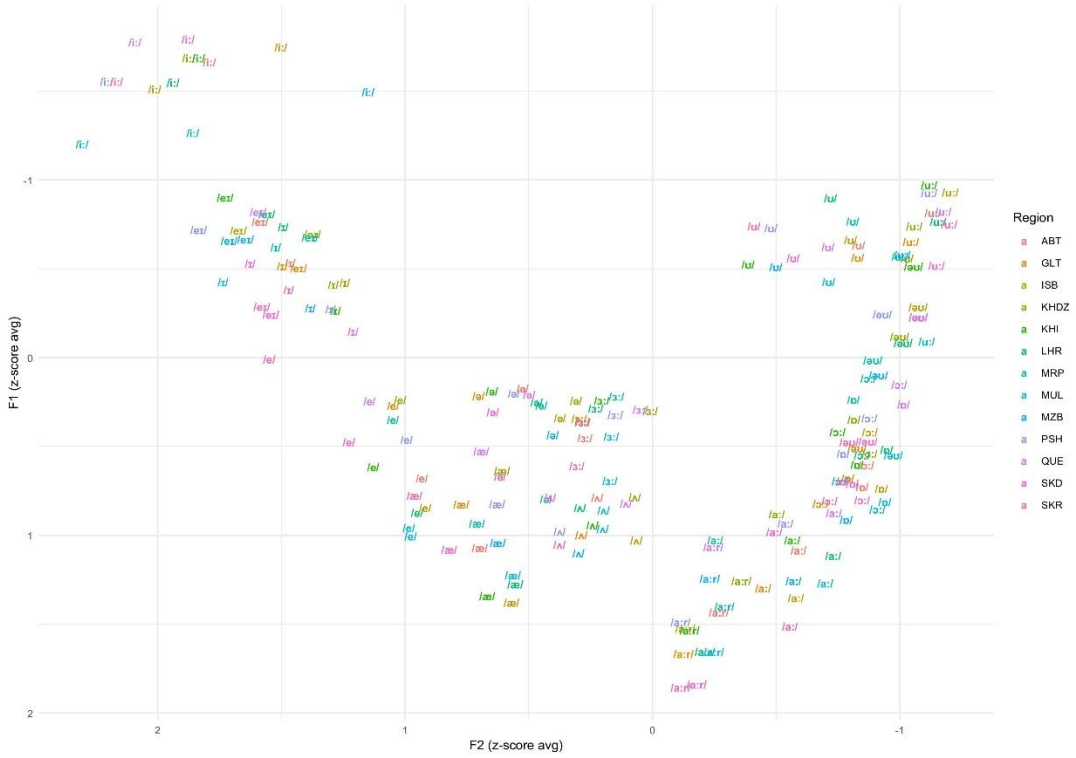
4. Results and Analysis

The analysis revealed systematic variation in Pakistani English vowels across regions and between genders. Statistical testing confirmed significant effects of both social and linguistic factors, highlighting the influence of local language ecologies and global phonetic trends on vowel realization.

Z-score normalization was applied to formant values (F1, F2) to control for

anatomical differences among speakers, ensuring comparability across individuals. This method standardizes each speaker's data by centering around the mean and scaling by the standard deviation, allowing group-level vowel patterns to emerge more clearly.

Figure 1: Showing Plot for 15 Vowels in 13 Regional Varieties of Pakistani English (Females)

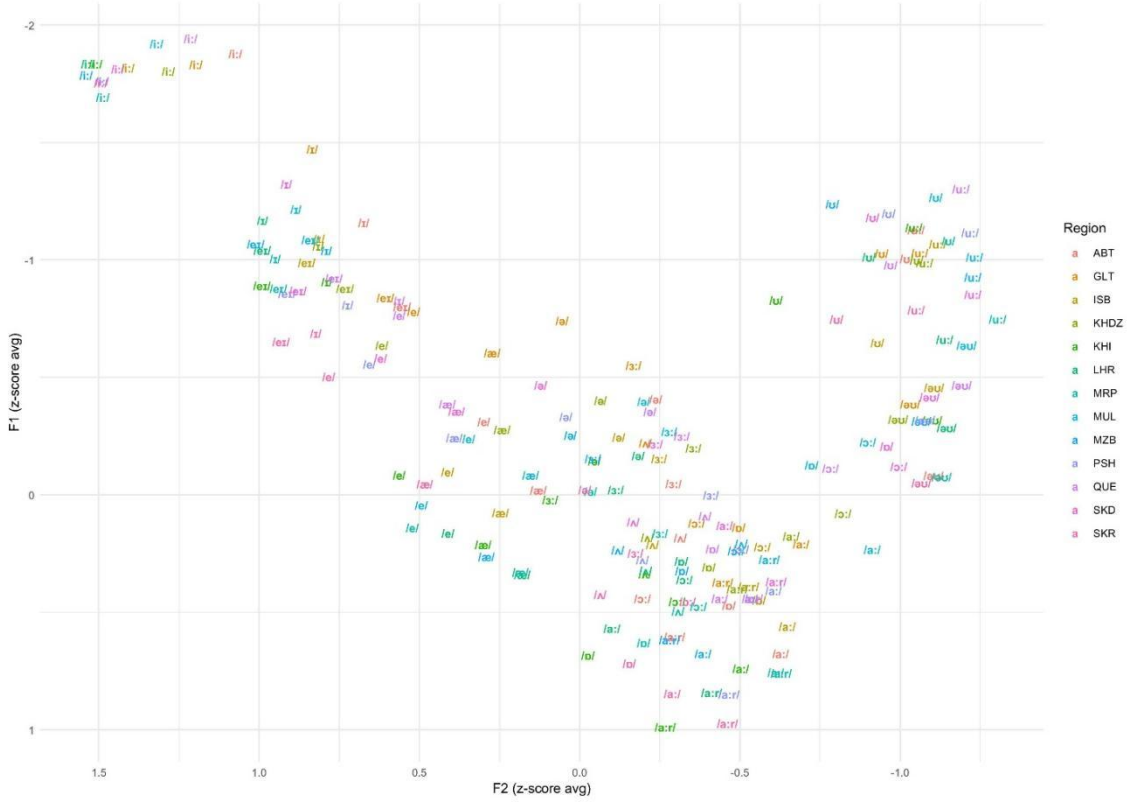


Turning to the female speakers, the vowel space plots across the thirteen Pakistani regions reveal clear regional variation in vowel realization. Overall, the distribution forms the expected triangular vowel space, with high front vowels (/iː, ɪ/) placed at the upper left, high back vowels (/uː, ʊ/) at the upper right, and low vowels (/aː, æ, ʌ/) at the bottom. Urban centers such as Karachi, Lahore, and Islamabad exhibit a more dispersed vowel space with stronger front–back contrasts, particularly in the realization of front vowels, which tend to be more advanced (higher F2 values). In contrast, northern and rural regions such as Skardu, Gilgit, and Sukkur display a more compressed vowel space, with front vowels less advanced and central vowels more centralized. Punjabi and Saraiki-speaking regions (Lahore, Multan) demonstrate more open low vowels (higher F1), reflecting substrate influence from local languages.

Meanwhile, back vowels in Multan and Muzaffarabad show a tendency toward fronting, aligning with global English patterns of /u:/ fronting, while Quetta and Peshawar maintain more conservative, back realizations. These results suggest that female speakers participate in international vowel shifts while simultaneously reflecting localized substrate influences.

For male speakers, the vowel space plot shows a well-defined distribution of Pakistani English vowels, with F2 on the x-axis (reversed) placing front vowels to the left and F1 on the y-axis (reversed) positioning high vowels at the top.

Figure 2: Showing Plot for 15 Vowels in 13 Regional Varieties of Pakistani English (Males)



This orientation creates the expected vowel quadrilateral: /i:/ (IY1) appears high and front, /a:/ (AA1) is low and central-back, and /u:/ (UW1) is high and back. Male speakers' vowel spaces are generally lower and less dispersed than those of females, which aligns with known sex-based formant differences, but the overall vowel contrasts remain clear. Front vowels (/i:/, /ɪ/, /e/) are tightly clustered, showing stability, while low vowels (/æ/, /a:/) exhibit greater height variation, suggesting regional or sociolinguistic influence. Back vowels (/u:/, /oʊ/, /ɔ:/) show regional

fronting and centralization, with some dialects reducing backness. The mid-central vowels (/ɜ:/, /ʌ/) display noticeable spread, further reflecting dialect contact and substrate influence. Overall, male speakers show stability in the vowel system, though with subtle regional differentiation in mid and back vowels.

A direct comparison of male and female vowel spaces highlights both shared regional patterns and gender-based contrasts. Female speakers exhibit a larger and more dispersed vowel space, with greater front–back contrasts and more advanced front vowels, particularly in urban centers like Karachi, Lahore, and Islamabad. Their articulation aligns with global trends of vowel fronting and lowering, especially for /u:/ and low vowels, reflecting sociolinguistic dynamism and influence from international English norms. In contrast, male speakers display a more compressed vowel space, with overall lower formant values (F1 and F2) due to physiological differences, leading to less dispersion and tighter vowel clustering. While both genders show substrate influence from regional languages—such as Punjabi and Saraiki impact on vowel openness and Quetta/Peshawar's conservative back vowel realizations—female speakers' patterns indicate stronger participation in ongoing vowel shifts and regional differentiation, whereas male speakers' vowels appear more conservative and centralized. This comparison underscores the interplay of biological, social, and regional factors in shaping Pakistani English vowel production.

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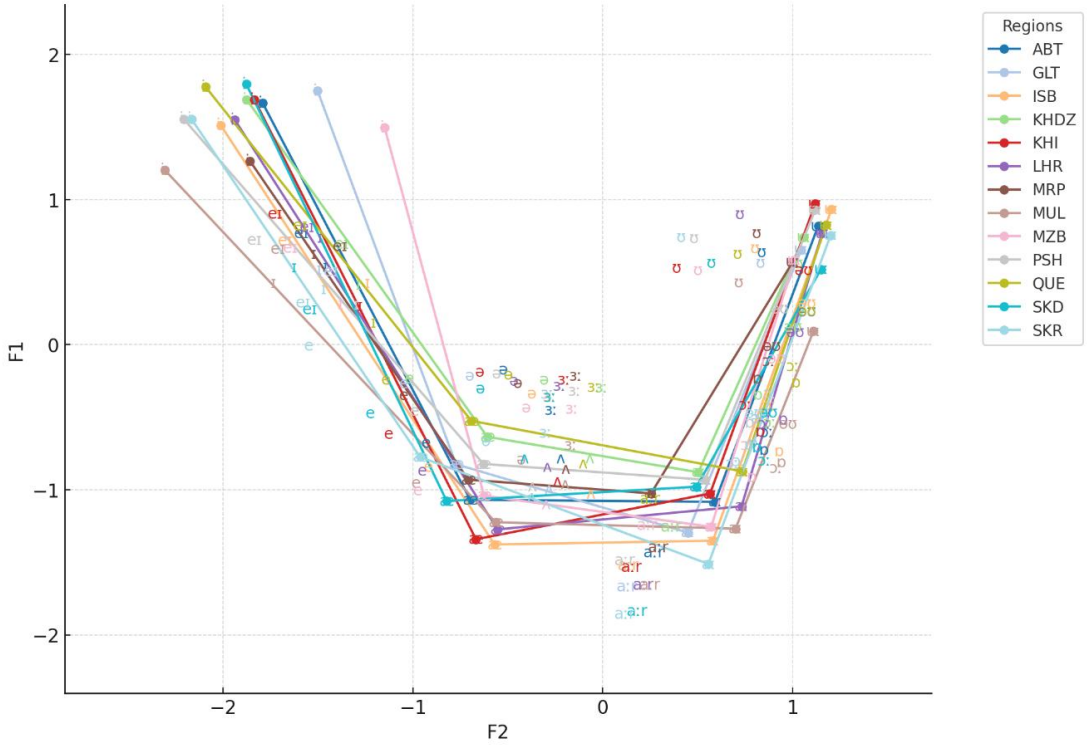
Figure 3: Showing Quadrilateral vowel plots for 13 Pakistani English Regional Varieties (Females)



Finally, the combined vowel quadrilateral plots further illustrate these trends by offering a holistic view of vowel distributions across speakers and regions. For female speakers, the quadrilaterals are more dispersed and elongated, consistent with sex-based formant differences and sociophonetic tendencies. Urban centers (Karachi, Lahore, Islamabad) show the largest quadrilaterals, with fronted high vowels and stronger contrasts, while northern and rural regions (Skardu, Gilgit, Sukkur) display more centralized patterns. Punjabi and Saraiki-speaking regions reveal lowered low vowels, while Quetta and Peshawar maintain conservative back vowel placements. Taken together, these plots confirm that female speakers lead in dispersion and fronting, reinforcing their role in driving sound change within Pakistani English.

The quadrilateral plot, aligned with the IPA trapezium, demonstrates a balanced triangular vowel system where contrasts of height and backness are clearly represented. The high front vowel /iː/ anchors the upper left, /uː/ the upper right, and /aː/ and /æ/ define the low positions, enclosing the acoustic envelope of the vowel inventory. This structural arrangement highlights the way Pakistani English

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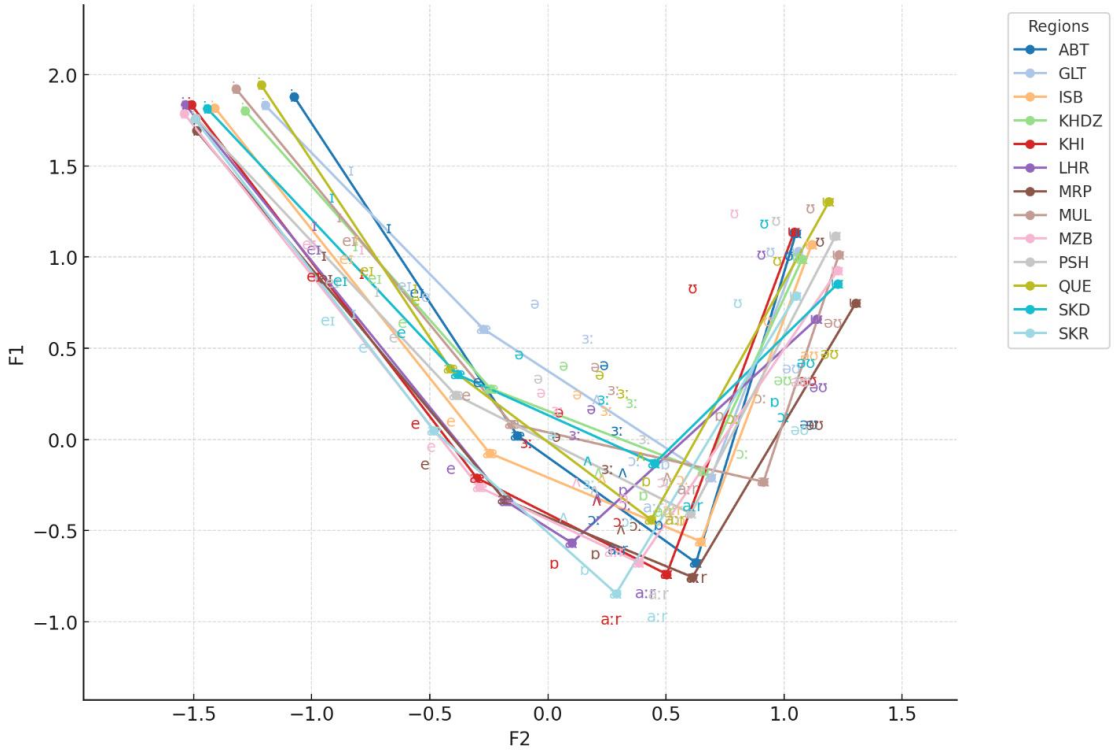
maximizes distinctiveness while reflecting both global phonetic shifts and local language contact effects.

Figure 4: Showing Quadrilateral Vowel Plots for 13 Pakistani English Regional Varieties (Males)



The male vowel quadrilateral plot across thirteen Pakistani regions displays a more compact vowel space compared to females, consistent with physiological differences in vocal tract size and the resulting lower F1 and F2 values. The chart retains the conventional triangular orientation, with front vowels (/iː/, /ɪ/, /e/) positioned at the upper left, high back vowels (/uː/, /ʊ/) at the upper right, and low vowels (/aː/, /æ/) at the bottom. While male speakers' quadrilaterals are less dispersed and more tightly clustered, essential front–back and height contrasts remain intact, indicating a stable but reduced vowel range relative to female speakers.

Despite this overall compression, regional distinctions remain visible. Urban centers such as Karachi, Lahore, and Islamabad display wider vowel spaces with stronger front–back contrasts, while northern and rural regions (Skardu, Gilgit, Sukkur) reveal narrower, centralized quadrilaterals. Punjabi- and Saraiki-speaking areas (Lahore, Multan, MRP) show lowered low vowels and stable mid-central

vowels, pointing to substrate influence, whereas back vowel fronting is less marked than in female speech. Nonetheless, slight /uː/ centralization appears in Multan and Muzaffarabad, aligning with international English trends. Overall, male vowel production reflects both anatomical constraints and sociophonetic tendencies toward conservatism, contrasting with the greater variability and innovation observed in female speakers.

4.1 Combined Plots

This vowel plot illustrates the overall distribution of vowels in F1–F2 space, aligned with the IPA trapezium orientation. The high front vowel /iː/ is positioned at the top-left corner, while the low front /æ/ marks the bottom-left edge of the vowel space. Back vowels are concentrated on the right side, with /uː/ at the high back position and /aː/ and /aːr/ occupying the low back corner. Central vowels such as /ə/, /ɜː/, and /ʌ/ cluster near the center, reflecting their intermediate articulatory positions. The arrangement shows a well-defined triangular vowel system where contrasts of height (e.g., /iː/ vs. /aː/) and backness (e.g., /iː/ vs. /uː/) are clearly represented. This distribution highlights the balance of front, central, and back vowels, demonstrating how the vowel space is used to maximize acoustic distinctiveness.

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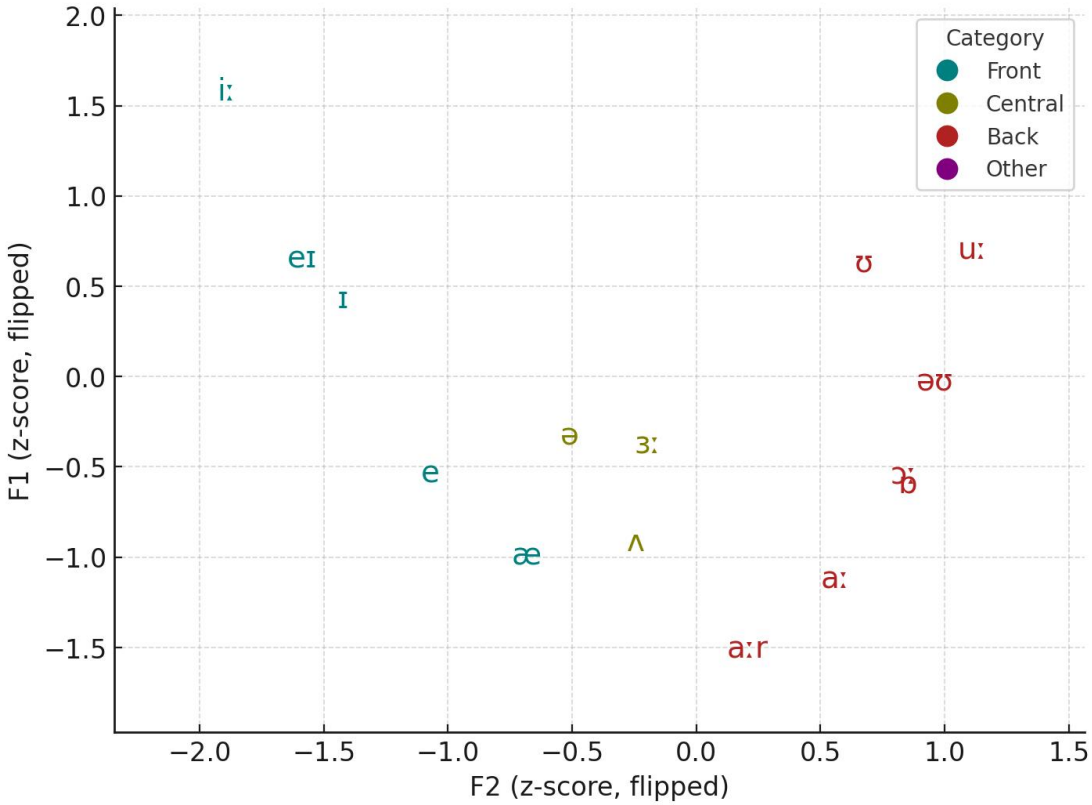
Figure 5: ***Showing Mean Vowel Plot for Pakistani English (Females)***



This plot shows the vowel space with the quadrilateral formed by the corner vowels /iː/, /æ/, /aː/, and /uː/, which define the boundaries of the system. The axes are oriented so that F2 decreases from left to right and F1 increases downward.

The high front vowel /iː/ appears at the top-left, anchoring the front-high region, while /æ/ lies lower and further right, marking the low front corner. On the back side, /uː/ sits in the top-right as the high back vowel, and /aː/ occupies the lower-right edge as the low back anchor. Together these four vowels form the quadrilateral area, shaded here to represent the maximal vowel space used.

Other vowels cluster within this space: central vowels (/ə/, /ɜː/, /ʌ/) occupy the middle region, intermediate front vowels (/e/, /ɪ/, /eɪ/) sit between /iː/ and /æ/, and mid back vowels (/ɔː/, /ɒ/) lie between /uː/ and /aː/. This arrangement demonstrates a well-structured vowel system where contrasts in height (F1) and backness (F2) are maximized, and the shaded quadrilateral highlights the articulatory-acoustic envelope of the vowel inventory.

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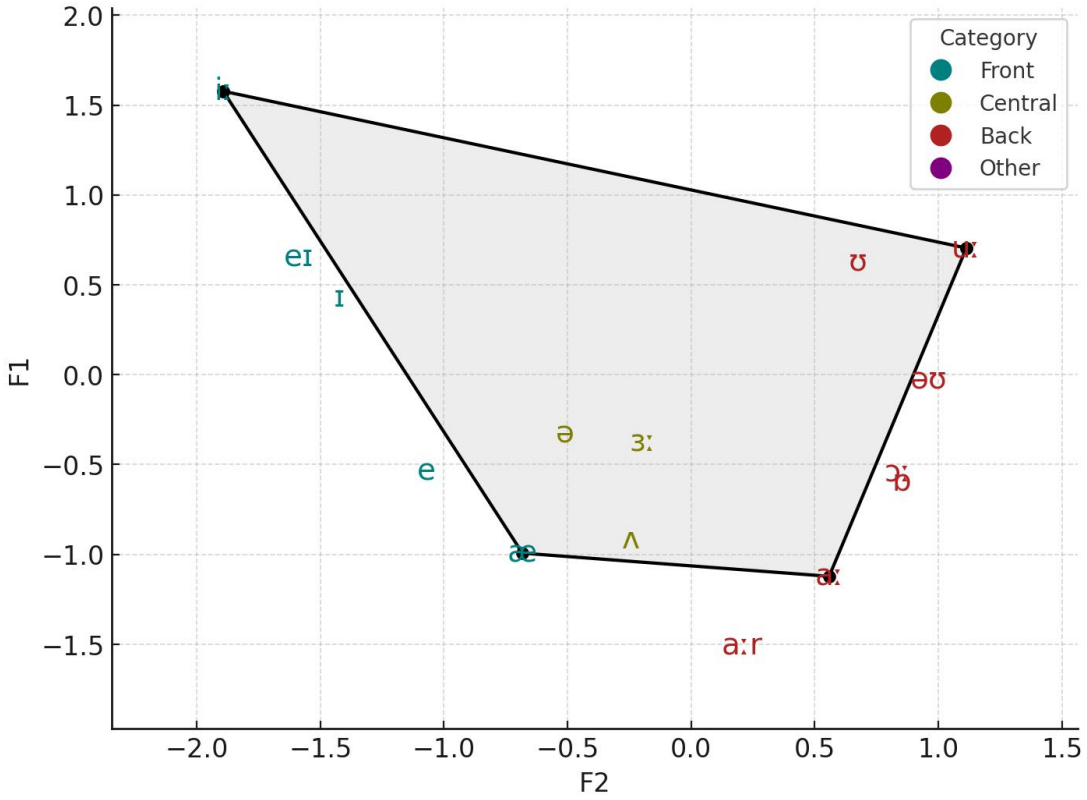
Figure 6: Showing Quadrilateral Mean Vowel Plot for Pakistani English (Females)



This plot represents the vowel space of Pakistani English male speakers, shown in normalized F1–F2 z-score space and aligned with the IPA trapezium. The front vowels are distributed on the left side, with /iː/ (F1 ≈ –1.9, F2 ≈ –1.5) anchoring the high front position, while /ɪ/ (F1 ≈ –0.9, F2 ≈ –1.0), /e/ (F1 ≈ –0.3, F2 ≈ –0.6), and /æ/ (F1 ≈ –0.1, F2 ≈ –0.3) occupy progressively lower front regions. The central vowels /ə/ (F1 ≈ 0.3, F2 ≈ –0.1), /ɜː/ (F1 ≈ 0.2, F2 ≈ 0.0), and /ʌ/ (F1 ≈ –0.2, F2 ≈ 0.2) cluster near the center of the vowel space, reflecting intermediate articulations typical of Pakistani English. The back vowels extend to the right side, with /uː/ (F1 ≈ 1.0, F2 ≈ 1.2) and /ʊ/ (F1 ≈ 1.0, F2 ≈ 0.9) marking the high back corner, while /ɔː/ (F1 ≈ –0.2, F2 ≈ 0.5), /ɒ/ (F1 ≈ –0.3, F2 ≈ 0.4), and the low back vowels /aː/ (F1 ≈ –0.5, F2 ≈ 0.5) and /aːr/ (F1 ≈ –0.6, F2 ≈ 0.5) form the lower back region. Overall, the plot shows a compact but acoustically distinct vowel system in Pakistani English male speech, with strong front–back contrasts (/iː/ vs. /uː/), height contrasts (/iː/, /uː/ vs. /aː/, /æ/), and central vowels occupying their expected positions. The normalization highlights the reduced vowel space typical of male speakers compared to females, while still

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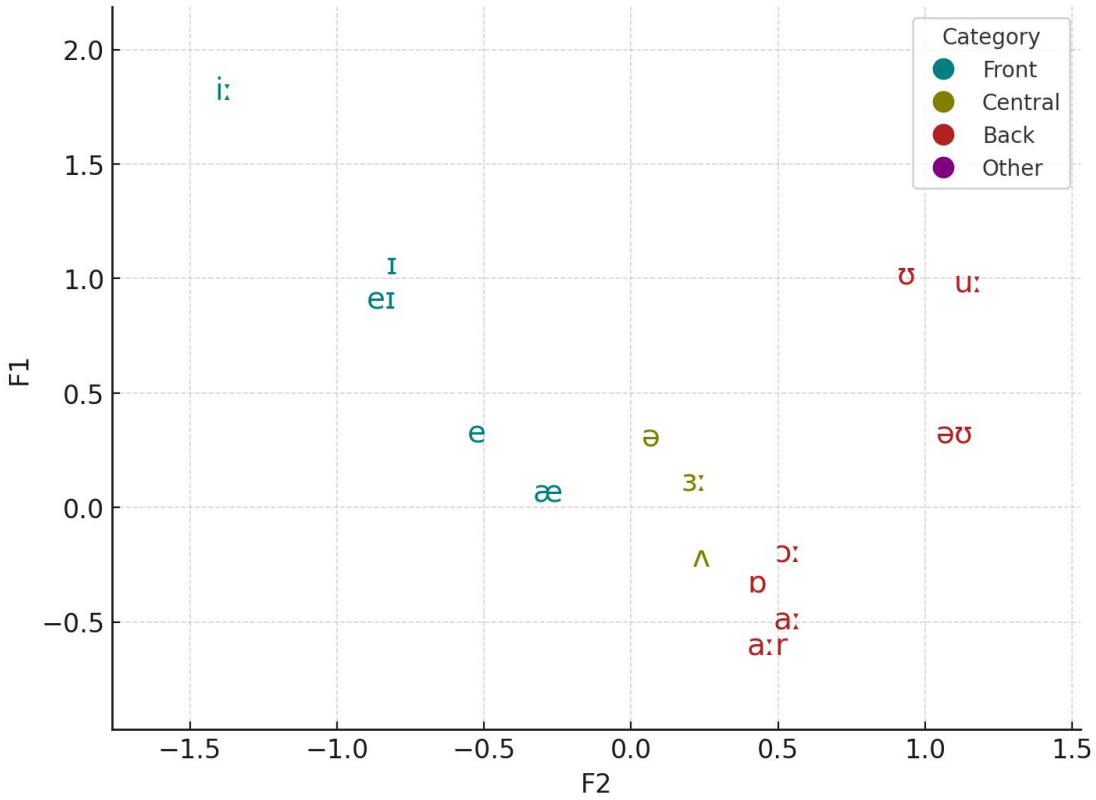
preserving the triangular structure of the Pakistani English vowel inventory.

Figure 7: ***Showing Mean Vowel Plot for Pakistani English (Males)***



In the Pakistani English male vowel plot (normalized F1–F2 space, IPA orientation), the corner vowels /iː–æ–aː–uː/ enclose an area of 2.538, indicating a comparatively compact vowel space. This is smaller than the corresponding female area we computed earlier (4.505), reflecting the typical male–female difference in vowel space expansion while preserving clear front–back and height contrasts across the system.

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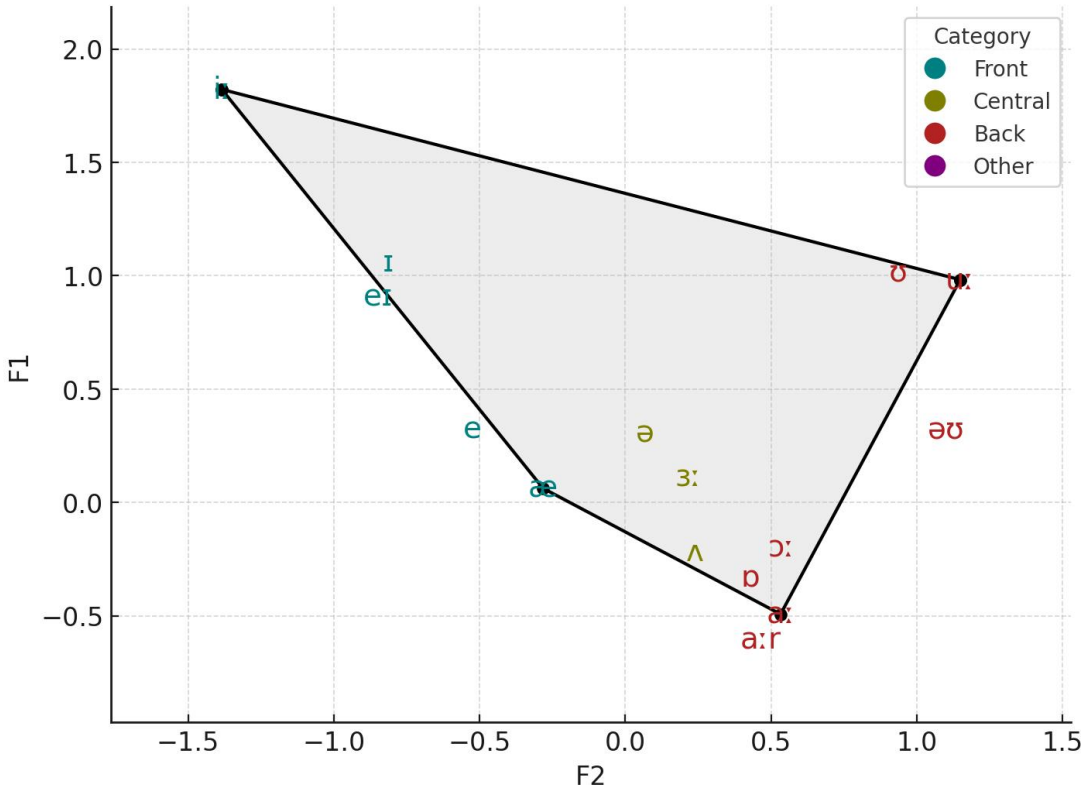
Figure 8: Showing Quadrilateral Mean Vowel Plot for Pakistani English (Males)



Viewed through a dispersion lens, the Pakistani English male vowel system is compact, with several areas of crowding. The front region is relatively tight: /ɪ/, /eɪ/, /e/, and /æ/ sit close together beneath the corner /iː/, indicating limited spacing among mid- and low-front vowels and an increased risk of overlap in running speech. The back region is even more compressed: the high back pair /uː–ʊ/ are near each other, and the low/mid backs /ɔː, ɒ, aː, aːr/ cluster along the right edge, leaving small distances between neighboring categories. Central vowels /ə, ɜː, ʌ/ also form a tight cluster around the center. Overall dispersion is therefore low, especially in the back and central zones, with the largest separations occurring only at the periphery (e.g., between /iː/ and the low backs). This pattern suggests reduced perceptual spacing for several contrasts—most notably /uː–ʊ/, /e–æ/, and among the central vowels—within an otherwise well-structured but densely packed male vowel space.

4.2 Comparison of Plots

This comparison plot of Pakistani English female and male vowels in normalized F1–

F2 space shows a consistent pattern of gender-based dispersion differences. Female vowels (red) occupy a larger and more expanded space (≈ 4.505 z-score units²), while male vowels (blue) are shifted inward, forming a smaller and more compact system (≈ 2.538 units²). For the front vowels, females produce /iː, ɪ, e, æ/ with lower F1 values (higher articulation) and more negative F2 values (greater fronting), whereas males show comparatively lowered and less fronted realizations. In the back region, females place /uː, ʊ/ higher and slightly fronter, while males realize them with higher F1 (lower tongue position) and more back placement. The low back vowels (/aː, aːr, ɒ, ɔː/) are also lower and backer in male speech, contributing to the overall compression of their vowel space. Central vowels (/ə, ɜː, ʌ/) remain relatively close between the two groups but are still somewhat more centralized for males. Altogether, the plot demonstrates that female speakers maintain clearer front–back and height contrasts through wider dispersion, while male speakers exhibit reduced spacing, leading to a more compact vowel system.

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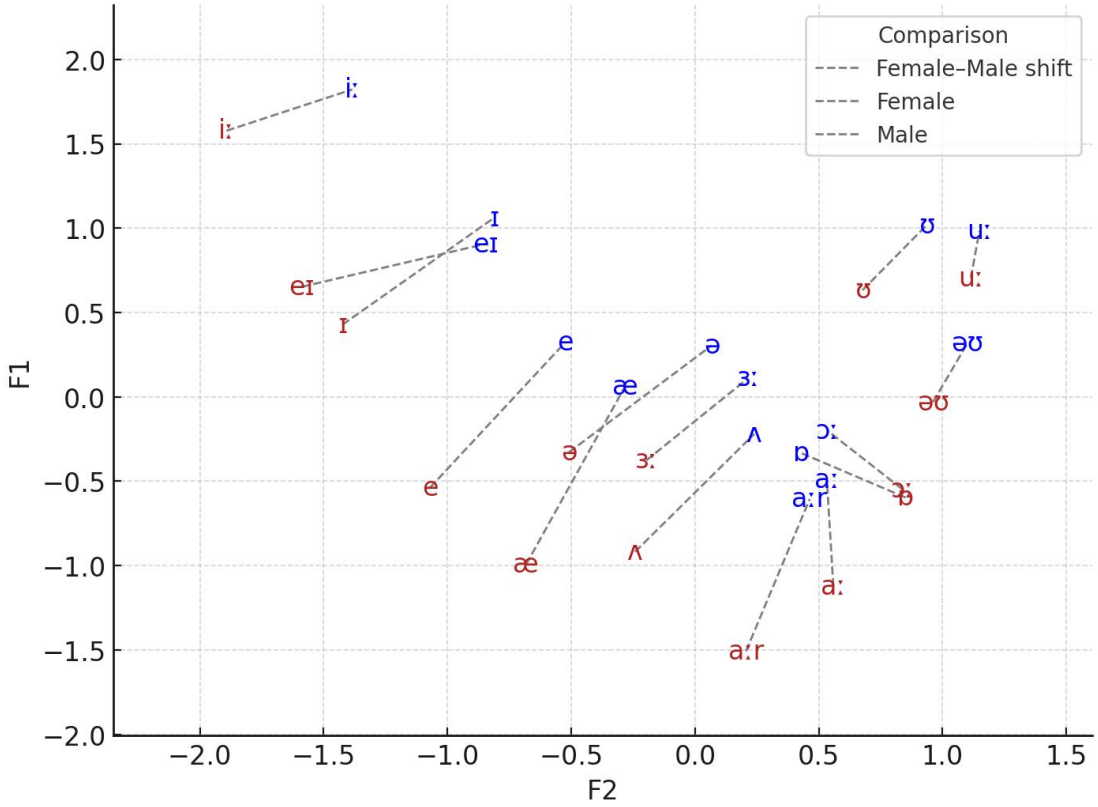
Figure 9: ***Showing Comparison of Mean Values of Vowels (Female vs Male)***



The analysis of vowel space areas revealed that female speakers exhibited a larger quadrilateral vowel space (4.51 z-score units²) compared to males (2.54 z-score units²), making the female space approximately 78% larger. Overlap analysis showed that the intersection between male and female vowel spaces was 1.75 units², with a total union of 5.29 units². This yielded a Jaccard index of 0.33 and a Dice coefficient of 0.50, indicating moderate similarity between the two distributions. Importantly, about 69% of the male vowel space overlapped with the female space, whereas only 39% of the female space overlapped with the male. These findings confirm that the male vowel space lies largely within the female space, reflecting females' greater articulatory dispersion and alignment with broader sociophonetic trends.

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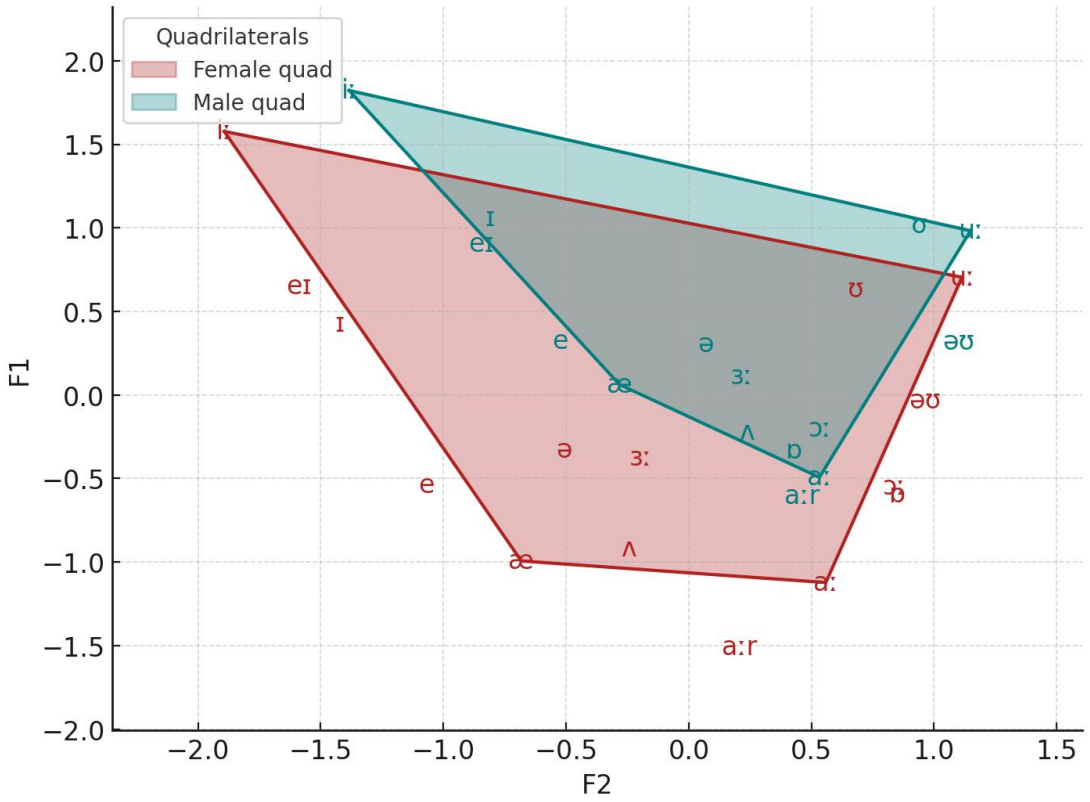
Figure 10: Showing Quadrilateral Plot of Comparison of Mean Values of Vowels (Female vs Male)



This overlay plot compares the vowel quadrilaterals of Pakistani English females (red) and males (blue) in normalized F1–F2 space, highlighting clear differences in dispersion. The female quadrilateral area is 4.505 z-score units², whereas the male quadrilateral area is much smaller at 2.538 units², confirming that females maintain a more expanded vowel space. The overlap region shows that while both groups share common articulatory space, females extend further both in the front region (/iː, e, æ/) and in the low region (/aː, aːr/), giving greater dispersion along both the height (F1) and front–back (F2) dimensions. Males, by contrast, compress their vowels inward, especially in the back corner (/uː, ʊ, ɔː/), where spacing is reduced, and in the low region, where /aː/ and /aːr/ sit closer to the center.

In terms of dispersion, the female system displays wider spacing between adjacent vowels: for example, /iː/ to /æ/ covers a greater F1 range, and /iː/ to /uː/ spans a broader F2 distance compared to males. Male vowels, however, are tightly packed, with minimal separation among central vowels (/ə, ɜː, ʌ/) and among back vowels (/uː,

ʊ, ɔː/), which risks perceptual overlap. Overall, this plot shows that Pakistani English females maintain clearer vowel contrasts due to greater dispersion, while male speakers exhibit a compressed system, with reduced distinctiveness especially in the back and central zones.

4.3 Comparison of Quadrilateral Plots

The comparison of male and female vowel quadrilateral plots across thirteen Pakistani regions highlights clear gender-based acoustic and sociophonetic differences. Female speakers display a larger, more expanded vowel space, with wider front–back and height contrasts, reflecting their naturally higher formant frequencies and a sociolinguistic tendency to adopt or lead in vowel shifts. In contrast, male speakers' vowel spaces are more compact and centralized, with tighter clustering of vowel categories and less extreme articulatory targets. While both genders share the same overall triangular vowel structure, female speakers' quadrilaterals are more elongated, particularly in urban regions such as Karachi, Lahore, and Islamabad, where female speakers show strong fronting of high vowels and greater dispersion of low vowels, suggesting active participation in international trends like /uː/-fronting. Male speakers, however, exhibit more conservative vowel realizations, especially in back vowels, with regional patterns appearing less pronounced.

Substrate influence from Punjabi, Saraiki, and northern languages is evident for both genders, but it is more acoustically visible in female speech, where low vowels (/aː/, /æ/) show greater lowering and openness, and northern dialects display stronger centralization. Male speakers maintain these patterns but in a narrower acoustic range, reinforcing stability. Overall, the comparison indicates that female speakers produce clearer vowel contrasts and demonstrate greater regional variation, while male speakers favor centralized, less dispersed vowels, reflecting both physiological constraints and sociophonetic norms. This supports broader findings that women often drive sound change and exhibit more dynamic vowel articulation, whereas men's vowel systems tend to be more conservative and less variable.

4.4 Anova Results

The two-panel heatmap shows where Karachi differs from other Pakistani varieties in vowel height (F1), separately for females (left) and males (right) — light/whitish cells

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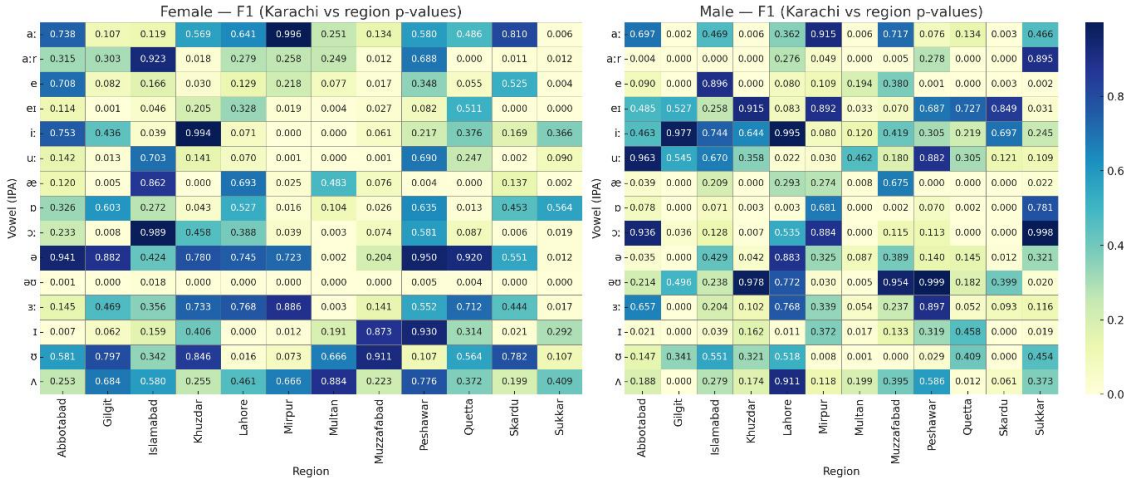
= small p (significant), dark = large p (not significant).

Figure 11: Heatmaps Showing Significant Values for F1 Females and Males



Overall pattern: many front and diphthong vowels show significant F1 differences for female speakers, while low/back and some central vowels show the strongest F1 differences for male speakers. In the female panel, vowels such as /ɪ, e, eɪ, æ, əʊ/ repeatedly return significant p-values against several regions (especially northern and highland areas), indicating that female vowel height in Karachi is consistently different from Abbottabad/Gilgit/Skardu/Quetta and a few other cities. In the male panel, significant F1 contrasts concentrate on low/back items (e.g. /aːr/, /ɒ/, /ɔː/) and a few central vowels, again most often vs. Gilgit, Skardu, Quetta and Khuzdar — showing that male height differences from Karachi are strongest in those regions.

In short: gender × region effects on vowel height are systematic but asymmetrical — females show wider, front-oriented height differences across many regions, while males show more concentrated height differences in the low/back part of the vowel space; the biggest regional departures from Karachi occur in the northern/highland and some western cities.

This two-panel F2 plot compares Karachi to other Pakistani English varieties (left = female, right = male); light (near-white) cells show small p-values (significant male–female differences in F2) while dark cells are non-significant.

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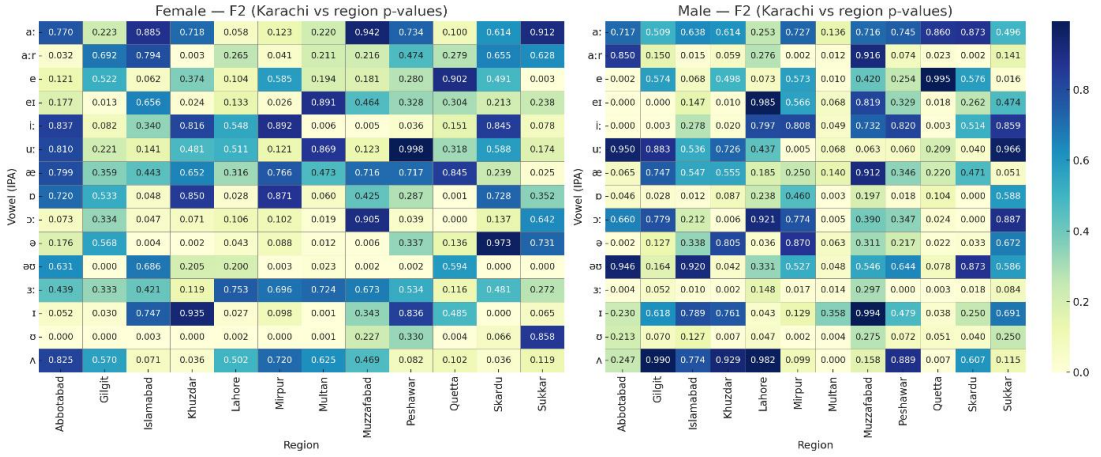
Figure 12: Heatmaps Showing Significant Values for F2 Females and Males



In the female panel, significant F2 differences are widespread: many front vowels (e.g. /iː, ɪ, e, eɪ, æ/) and several back/central vowels (e.g. /ʊ, ɔː, ɒ, ə/) show consistent Karachi vs-region contrasts across northern and highland sites (Abbottabad, Gilgit, Skardu) and some western/urban centres (Quetta, Islamabad). This indicates that female speakers' vowel fronting/backing varies systematically by region — Karachi females tend to be more fronted for a number of vowels compared with several other varieties, producing clearer regional F2 shifts.

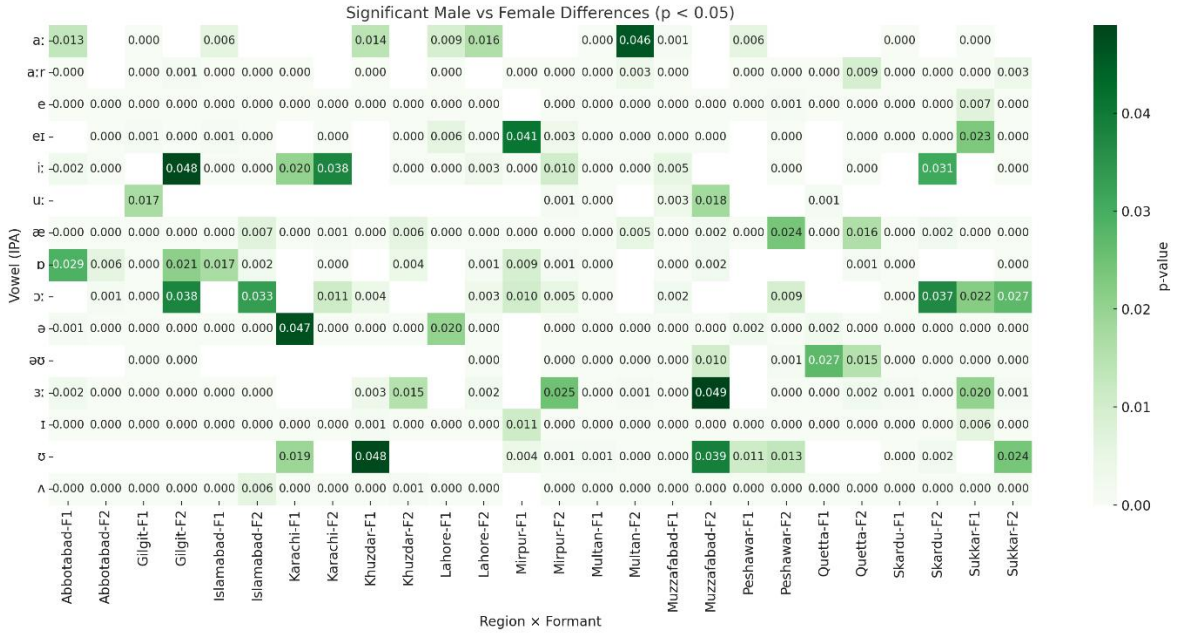
In the male panel the pattern is more focal: F2 differences occur for a subset of vowels (notably central and back vowels) concentrated in a smaller set of regions (again strong in Gilgit, Skardu and Quetta, and parts of the northwest). High front and high back vowels show some gendered F2 shifts too, but these are less widespread than in females.

Overall, F2 (frontness/backness) variation is more regionally extensive in females (broader fronting/backing differences across varieties), whereas in males significant F2 effects are more localized and tend to involve central/back vowels in particular regions.

This heatmap (Figure 12) illustrates gender-based vowel differences across Pakistani English varieties. The most consistent contrasts appear for front vowels like /æ/, /ɪ/, and /e/, as well as central vowels such as /ə/, showing widespread male–female differences in both vowel height (F1) and frontness/backness (F2) across regions. Central vowels (/ɜː/) and back vowels (/ɒ/, /ɔː/) also reveal significant differences, particularly in urban centers like Islamabad, Karachi, and Skardu,

suggesting localized gender-driven shifts. In contrast, peripheral vowels (/aː/, /uː/) display much fewer differences, indicating greater stability across genders. Overall, the findings show that gender variation in Pakistani English varieties is concentrated in the front and central vowel space, while high back vowels remain relatively stable across regions.

Figure 13: Heatmaps Showing Significant Values of Vowels for Females and Males



The heatmap (Figure 13) shows that gender-based vowel differences in Pakistani English are most widespread for front vowels (/æ/, /ɪ/, /e/) and central vowels (/ə/, /ʌ/, /ɜː/), which exhibit significant contrasts in nearly all regions for both height (F1) and frontness/backness (F2). In contrast, back vowels like /ɒ/, /ɔː/, and /aːr/ show strong gender effects mainly in F1 (height), while high vowels such as /iː/ and especially /uː/ remain relatively stable across regions.

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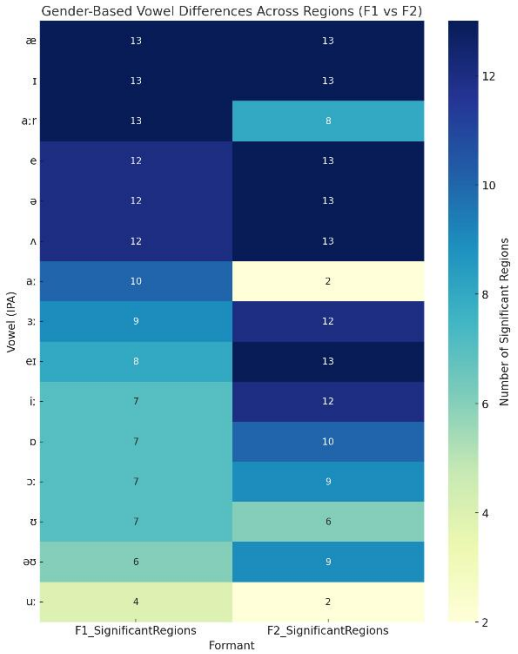
Figure 14: Heatmap Showing Gender-based Vowel Diffrences Across Regions (F1 vs F2)



This pattern highlights that male–female variation is concentrated in the front and central vowel space, whereas peripheral vowels are more resistant to gender-based dispersion.

4.5 Discussion

This study set out to document regional vowel variation across Pakistani English (PakE) and to examine how gender interacts with regional differences. Using z-score–normalized F1 and F2 measures and applying one-way ANOVAs with post hoc pairwise comparisons (Karachi vs. each region), the results reveal three robust outcomes: (1) geographically structured vowel differences across Pakistan, (2) systematic gender differences in vowel-space dispersion, and (3) vowel-specific loci of instability that accord with contact effects and theoretical expectations.

First, regional structure is pronounced and geographically patterned. Northern and highland sites (e.g., Gilgit, Skardu, Abbottabad) and several western centres (e.g., Quetta, Khuzdar) diverge repeatedly from coastal/urban sites (Karachi, Lahore, Islamabad) in both F1 and F2. Front and central vowels—especially /æ, ɪ, e, ə, eɪ, əʊ/—display the largest regional spread in F2 (frontness/backness), whereas low and back vowels (e.g., /aːr, ɒ, ɔː/) show the most pronounced regional differences in F1

(height). These empirical patterns mirror earlier descriptive work documenting local phonetic idiosyncrasies and substrate influence in PakE (Sheikh, 2012; Baloch & Qureshi, 2015) and align with corpus-level studies of inter-varietal differences (Bilal et al., 2021; Kousar, 2023).

Second, gender systematically conditions the spatial configuration of vowels. Female speakers occupy a substantially larger vowel area (quadrilateral area ≈ 4.505 z-units²) compared with males (≈ 2.538 z-units²). Overlap metrics indicate that much of the male vowel space is contained within the female space (intersection ≈ 1.751; Jaccard ≈ 0.331; Dice ≈ 0.497), meaning female productions are more dispersed and, by implication, more perceptually separable. This gender asymmetry dovetails with long-standing variationist generalizations on women's role in sound change (Labov, 1990) and with sociophonetic findings that women often lead articulatory expansion or hyperarticulation in undergoing changes.

Third, vowel-level results identify hotspots of instability. Front vowels (/æ, ɪ, e/) and several diphthongs (/eɪ, əʊ/) are the most regionally and gender-sensitive categories; many central vowels (/ə, ɜː/) and some back vowels (/ɒ, ɔː, aːr/) also show robust effects. Counting how many regions exhibit significant male–female contrasts demonstrates that /æ/ and /ɪ/ are especially affected across the dataset. Formant-specific patterns emerge too: diphthongs and front vowels show widespread F2 and F1 variation in females, whereas males show pronounced F1 variation in low/back vowels and more localized F2 variation in some central/back vowels. This suggests that ongoing acoustic change and regional differentiation in PakE are likely to propagate through front and central regions of the vowel space.

The observed patterns integrate neatly into several theoretical frameworks of phonological organization and sociophonetic change. Vowel Dispersion Theory predicts that vowel systems evolve toward configurations that maximize perceptual contrast by spacing categories as far apart as possible in acoustic space. The expanded female vowel space observed in our data supports this model, as greater dispersion minimizes perceptual crowding and reduces the likelihood of confusability between neighboring vowels (Liljencrants & Lindblom, 1972; Lindblom, 1986). Such expansion may also act as a precursor to ongoing sound change, since increased

distinctiveness in the acoustic signal can stabilize innovative variants and allow them to spread through the community.

Schneider's Dynamic Model of Postcolonial Englishes provides a broader sociolinguistic framework for interpreting the regional variability in Pakistani English. According to this model, postcolonial Englishes pass through phases of foundation, exonormative stabilization, nativization, endonormative stabilization, and differentiation (Schneider, 2007). The urban centres (Karachi, Lahore, Islamabad) demonstrate vowel dispersion patterns consistent with ongoing nativization coupled with partial orientation toward international English norms, leading to broader vowel spaces and the adoption of global tendencies such as /uː/ fronting. In contrast, peripheral varieties (e.g., Skardu, Gilgit, Quetta, Sukkur) display stronger substrate influence, with centralization and conservative back vowel realizations that reflect the phonological systems of local heritage languages. This divergence across regions suggests that Pakistani English is simultaneously negotiating global standardization pressures and local identity marking, which is typical of the differentiation stage in Schneider's framework.

Finally, variationist gender theory offers a social explanation for the differences between male and female vowel spaces. Labov (1990) and subsequent work have shown that women frequently lead in linguistic change, particularly in phonetic variables, due to their greater orientation toward overt prestige norms, stylistic innovation, and symbolic differentiation within the speech community. In our data, women's larger and more dispersed vowel spaces not only align with biological factors but also reflect sociophonetic dynamism, positioning them as potential vectors of change in Pakistani English. Male speakers, by contrast, exhibit more conservative and compressed vowel spaces, consistent with broader cross-linguistic findings that men tend to preserve centralized or less extreme vowel realizations. Together, these frameworks explain both the structural (dispersion-based) and social (gender- and region-based) forces shaping vowel patterns in Pakistani English.

These findings have practical implications. For sociolinguistic theory, the gendered dispersion pattern supports models linking social factors (gender, urban orientation) to acoustic restructuring. For applied domains (speech technology,

language teaching), the results indicate that region- and gender-aware acoustic normalization will improve modeling and pedagogical targeting for PakE.

Table 2: ***Summary of Findings on Vowel Variation in Pakistani English***

Dimension	Findings	Interpretation
Regional variation	Clear geographic structuring: urban centers (Karachi, Lahore, Islamabad) show wider dispersion; northern/western sites (Gilgit, Skardu, Quetta) show centralization and conservative back vowels.	Consistent with Schneider's Dynamic Model: urban varieties orient toward global English norms, peripheral varieties reflect stronger substrate influence.
Gender differences	Female vowel space ≈ 78% larger than male space (4.51 vs. 2.54 z^2). Male vowel space largely contained within female (≈69% overlap).	Supports Variationist Gender Theory: women lead sound change via expanded dispersion, men preserve centralized targets.
Vowel-specific instability	Front vowels (/æ, ɪ, e/) and diphthongs (/eɪ, əʊ/) show strongest regional/gender sensitivity; low/back vowels also variable.	Aligns with Vowel Dispersion Theory: dispersion maximizes perceptual contrast; unstable categories are loci of change.
Overall pattern	Female-expanded and male-compressed vowel systems; regional divergence alongside global convergence trends.	PakE is in the differentiation stage: simultaneous stabilization, innovation, and localization.

In sum, PakE exhibits clear regional differentiation with gendered dispersion: females expand the vowel space (maximizing contrast) while males remain more compressed. These results integrate Vowel Dispersion Theory, Schneider's Dynamic Model, and variationist expectations about gendered change, and they identify concrete vowel and regional targets for future phonetic and sociolinguistic research.

5. Conclusion

This study provides a comprehensive acoustic account of regional and gender-conditioned variation in Pakistani English (PakE). Using z-score–normalized F1 and

F2 measurements from a balanced multi-city sample (208 speakers, 13 cities), and a combination of ANOVA, pairwise tests and targeted male–female comparisons, we found three clear conclusions. First, vowel production in PakE is regionally structured: front and central vowels (e.g., /æ, ɪ, e, ə, eɪ, əʊ/) show the greatest dispersion across cities in F2, while low/back vowels (e.g., /aːr, ɒ, ɔː/) show the largest regional differences in F1. Urban centres (Karachi, Lahore, Islamabad) tend toward broader, more "standardized" vowel systems, whereas peripheral and highland varieties (e.g., Gilgit, Skardu, Quetta, Khuzdar) show systematic centralization and local substrate effects.

Second, gender strongly conditions these regional patterns: female speakers occupy a substantially larger vowel area (quadrilateral ≈ 4.505 z-units²) than males (≈ 2.538 z-units²), and most of the male space lies inside the female space (intersection ≈ 1.751 z-units²). Females therefore exhibit wider dispersion—consistent with hyperarticulation and change-leadership—while males show a more compressed acoustic regime. Third, certain vowels are especially sensitive to regional and gender differences (notably /æ/ and /ɪ/, as well as several diphthongs and central vowels), identifying clear loci for ongoing and potential change in PakE.

Practically, these outcomes imply (a) that speech technology and pedagogical resources for PakE should incorporate region- and gender-sensitive normalization, and (b) that sociophonetic change in Pakistan is likely to proceed unevenly, with women and urban centres acting as vectors of expansion toward broader—or internationally aligned—targets.

Finally, the study has limitations that temper the conclusions and suggest directions for future work: z-score normalization facilitated cross-speaker comparison but obscures absolute frequency shifts; the speaker sample (university-connected) may underrepresent some sociolects; and multiple testing requires cautious interpretation of single p-values. Future research should combine production with perception experiments (to evaluate functional consequences of compressed male spaces), use mixed-effects models with sociolinguistic predictors (age, education, media exposure), and examine apparent-time cohorts to determine whether female dispersion predicts system-level changes in PakE.

5.1 Ethical Considerations

This study constitutes a component of the researcher's doctoral dissertation.

Funding Statement

This research received no external funding.

Conflict of Interest Statement

The author declares no conflicts of interest related to this study.

Data Availability Statement

The study is a part of my PhD thesis. This study builds on the findings of Mumtaz (2025), which presented the initial acoustic analysis of Pakistani English vowels. The present research extends that work by focusing on gender- and region-based variation. As the dataset was collected without external funding, it remains the intellectual property of the author and is not publicly available.

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