TRACKING PRONUNCIATION IMPROVEMENT: A FORMANT-BASED STUDY OF ENGLISH VOWELS IN PAKISTANI LEARNERS OF ESL

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Abstract:
The present study tracks the improvement in pronunciation of English words spoken by Pakistani learners of English. Teacher-led International Phonetic Alphabet (IPA) instruction is employed for the pronunciation among a group of 15 purposively selected students of 1st year studying in a public sector Pakistani university located in Lahore. A list of 15 most commonly mispronounced words of English was used before introducing IPA based instruction. After the intervention of 4 weeks, the same list of words was used as a post-test among the sample. Both the samples were analyzed using PRAAT software. Two vowel formants F1 and F2 were calculated and compared for each of the 15 words. The results and analyses found that there had been mixed trends of improvement in pronunciation of the words depicted by their vowel formants values. Sound recordings of three participants are presented for the understanding of the readers. Challenging vowel sounds for individual learners have been indicated with suggestions to improve.

Introduction

Pronunciation plays an indispensable role in English communication (Muhamad & Rahmat, 2020), as pronunciation refers to how people produce the sounds to make meaning when people speak the language. Pronunciation relates to tolerable standards of sounds' rhythm for different words (Al-khresheh, 2024). Pronunciation is the tangible production of speech sounds, stressing how the hearer grasps the sounds produced (Liu, Jones & Reed, 2022). Pronunciation is a crucial aspect of English language teaching and learning, significantly impacting learners' communicative competence and intelligibility (Trinh, Nguyen & Le, 2022). Despite its importance, pronunciation often receives insufficient attention in ESL/EFL classrooms (Nisreen, 2023) where factors affecting acquisition of pronunciation include age, motivation, native language influence, and exposure (Wang, 2023). Effective pronunciation instruction should integrate both segmental and suprasegmental features (Gabriel, 2023) and can be combined with other language skills like grammar and vocabulary (Jones, 2017). Teachers play a vital role in improving learners' pronunciation skills through various techniques and strategies (Asrul & Husda, 2022). Incorporating pronunciation into the curriculum can enhance students' overall communicative abilities, boost their confidence, and improve their listening skills (Sokyrska, 2023). To address the challenges in pronunciation teaching, educators should consider innovative approaches and integrate pronunciation instruction throughout language courses (Gabriel, 2023; Gilakjani, 2012). Effective communication in English is essential for Pakistani students who are learning English as a second language. While engaged in a conversation, pronunciation becomes a key aspect of effective communication as it can affect a learner's confidence, intelligibility, and overall language

proficiency (Ahmed, 2017). But research has shown that Pakistani ESL learners find it hard to pronounce English, which keeps them from communicating effectively (Fareed et al., 2016).

Pakistani ESL learners have been found to be handling the process of learning English pronunciation by interference from their native language, lack of exposure to native English speakers or incorrect pronunciation instructions (Gul et al., 2022; Fareed et al., 2016). In study done on difficulties seen by Sudanese EFL learners in learning pronunciation; it is found that many learners in their claims of what is less important than other areas of English language and that they do not give attention to pronunciation (Ahmed, 2017). A different study of challenges in speaking English from a secondary level Pakistani students also found that lack of exposure to English and only focusing on grammar instead of speaking skills are both factors in difficulties that these students have with pronunciation (Gul et al., 2022).

The International Phonetic Alphabet (IPA) can greatly facilitate the pronunciation learning of ESL/EFL learners across different contexts. A case study with Vietnamese adult learners (Trinh & Nguyen, 2022) and Bangladeshi textile engineering students (Uddin & Uddin, 2021) have shown positive impact revealing the success of IPA based instruction that have also been supported by the findings of the studies conducted among Indonesian high school students (Chuzaimah & Fadli, 2021) and Saudi university students (Rajab, 2013). Results from previous studies report that the IPA instruction has improved oral skills, phonological awareness and learner autonomy (Indrayani & Suherman, 2017; Setiyono, 2019). Besides, IPA symbols are looked at by some students as hard to learn at the initial stage but still know their use as helping to improve a student's pronunciation (Banu Suryaleksana et al., 2022). In general, these studies show that instruction of IPA in ESL/EFL classrooms is a useful method for improving students' pronunciation. The acquisition of native-like pronunciation is a long-term process, but these studies point out that the inclusion of phonetic transcription in language teaching can help learners improve their pronunciation more accurately and facilitate their learner autonomy.

Research is made attempting to examine patterns of similarity of difference between the vowel formants produced by the non-native English speakers and natives (Smith, 2019; Evanini and Huang, 2012). In some cases, however, dialect differences do exist in some acoustic properties, e.g., [1] values of the first formant (F1), which presumably reflect differences in tongue height and vowel backness. These variations are influenced by the speakers' native phonetic inventory (Azzahra, 2024) and their exposure to English language hinders their ability to communicate effectively (Fareed et al., 2016).

Studies have shown that Pakistani ESL learners face various challenges in learning English pronunciation such as interference from their native language, lack of exposure to native English speakers, and insufficient instruction in pronunciation (Gul et al., 2022). An example can be reported from Sudani perspective where it was found that many learners believe pronunciation is less important than other areas of the English language, and they often do not pay attention to their pronunciation (Ahmed, 2017). Similarly, a study on the challenges faced by secondary-level Pakistani students in speaking English found that factors such as a lack of exposure to English and a focus on grammar rather than speaking skills contribute to pronunciation difficulties (Gul et al., 2022).

The International Phonetic Alphabet (IPA) has been found to significantly improve pronunciation skills in ESL/EFL learners across various contexts. Studies have demonstrated positive effects on Vietnamese adult learners (Trinh & Nguyen, 2022), Bangladeshi textile engineering students (Uddin & Uddin, 2021), Indonesian high school students (Chuzaimah & Fadli, 2021), and Saudi

university students (Rajab, 2013). IPA instruction has been found to enhance oral skills, phonological awareness, and learner autonomy (Indrayani & Suherman, 2017; Setiyono, 2019). While some students perceive IPA symbols as challenging to learn initially, they generally recognize their usefulness in improving pronunciation (Banu Suryaleksana et al., 2022). Research has also shown that IPA training can assist learners in pronouncing difficult English words, particularly those with challenging vowels, silent sounds, and ambiguous sounds (Oh, 2019). Overall, these studies suggest that incorporating IPA instruction in ESL/EFL classrooms can be an effective approach to enhancing learners' pronunciation skills. While acquiring native-like pronunciation is a long-term process, these studies demonstrate that integrating phonetic transcription in language teaching can significantly benefit learners in developing more accurate pronunciation and fostering learner autonomy.

Patterns of similarity and difference between the vowel formant production of non-native English speakers and native speakers are examined through research. In approximately half of their vowel productions, non-native speakers show similar formant patterns to native speakers (Smith, 2019; Evanini and Huang, 2012). But in some instances, however, there are deviations in specific acoustic properties, e.g., [1] first formant (F1) values, which presumably account for the differences in tongue height and vowel backness. The speakers' native phonetic inventory and English (Azzahra, 2024) exposure to English influence these variations.

The International Phonetic Alphabet (IPA) has become a great means for understanding how various sounds should be pronounced by ESL learners. The IPA closes the gap between taught language to actual speech performance for the ESL learner. For instance, Al Abdely (2021) shows the usefulness of IPA training in solving pronunciation problems, e.g., low vowels by Iraqi learners. In the same way, Kalngan Mi-ing (2023) highlights the IPA's role in expounding these confusion vowels and consonant sound contrasts among the IPA learners.

By using IPA's systematic approach learners are able to independently decode unfamiliar words and improve their phonetic awareness (Klímová et al., 2023). Adding IPA training into ESL curriculums allows educators to help learners better understand the phonological nuances of English and to feel more confident with oral communication. Studies, for instance, that of Al Shaibani (2023), also highlight the IPA as an effective way to decrease speaking anxiety and rise in self-reassurance especially among female learners in Saudi Arabia.

The application of IPA in ESL education has further grown as the result of technological development. Abusahyon et al. (2023) discuss how AI driven tools and chatbots give personalized feedback on pronunciation. These tools help learners improve their pronunciation, suppress effects caused by the native language, and generally raise skills. In addition, as shown in Tai (2023), synchronous online teaching with IPA instruction may help bridge phonological gaps, especially in terms of remote learning settings.

There is research that indicates that vowel formants extracted by PRAAT type tools can uncover persistent pronunciation issues in non-native speakers. For example, in Syarfina (2023), instances of pronouncing of the monophthong schwa (as in /ə/) sound were frequently incoherent among non-native speakers, while in Mramboa and Ligembe (2022), difficulties in phonological skill acquisition were seen with Tanzanian learners. The findings point to the need to synergize phonetic instruction with language education to deal with specific linguistic barriers.

The present study thus focuses on IPA drills and addresses a gap in the literature by systematically analyzing how explicit phonetic training affects acoustic accuracy of vowel formants. Drawing from the already collected empirical insights of variability, technological available tools like

PRAAT, and reflecting practices, the research seeks to provide empirical grounding for the application of IPA based pronunciation instruction in the context of learning English as an additional language in Pakistan.

Research   Question:

How do IPA drills influence the accuracy of vowel formant production in non-native (Pakistani) English language learners?

Methodology:

This study investigates the effectiveness of International Phonetic Alphabet (IPA) based drills on the pronunciation of English vowel sounds by Pakistani learners of English. The methodology was based on a pre and posttest design with IPA training and formant analysis by PRAAT software. The researcher selected purposively selected fifteen learners who would serve as a sample of non-native speakers who face common pronunciation challenges. For this study, the participants were provided with informed consent forms for their voluntary participation. The subjects of the study were told that their recordings and data would be used for research purposes only and that results would be anonymized when reported.

Research Procedure

The study adopted the following procedure:

Pre-Test Recording

For each participant, a list of fifteen English words was given. In selecting these words, the researchers selected those vowel sounds that are particularly hard for Pakistani (non-native speakers) to pronounce (e.g. /ɪ/, /æ/, /ʌ/, etc.). The words to be pronounced by the participants were given, and their speech was recorded in a quiet environment in order to minimize background noise in wav format. This was a pretest analysis which established the baseline formant values for each learner's vowel sounds according to Azzahra's (2024) recommendations of baseline where pretest analysis can reduce formant variability.

Orientation and IPA Training

After the pre-test, the participants were oriented to the IPA for a four-week period by focusing on the vowel symbols present in the target words using IPA symbols accompanied with daily practice drills for 90minutes a day for five days in a week. Interactive sessions give you feedback and corrective measures which can be in the form of implementation followed by the methodology of Al Abdely (2021) that showed that explicit IPA training can help to improve vowel pronunciation formant patterns compared to native speakers in approximately half of their vowel productions (Smith, 2019; Evanini & Huang, 2012). However, deviations are frequently observed in specific acoustic properties, such as the first formant (F1) values, reflecting differences in tongue height and vowel backness. These variations are influenced by the speakers' native phonetic inventory and their exposure to English (Azzahra, 2024).

The following list of words and IPA transcript was shared with the participants for practice:

Sr. No.	Words	IPA transcript
1	Beneficent	/bɪˈnefəsənt/

2	Emergency	/ɪˈmɜː.dʒən.si/
3	Pleasure	/ˈpleʒ.ər/
4	Measure	/ˈmeʒ.ər/
5	So	/səʊ/
6	Earth	/ɜːθ/
7	Call	/kɔːl/
8	Specific	/spəˈsɪf.ɪk/
9	Particular	/pəˈtɪk.jə.lər/
10	Necessary	/ˈnes.ə.ser.i/
11	Preference	/ˈpref.ər.əns/
12	Slower	/ˈsləʊə/
13	Bathe	/beɪð/
14	Status	/ˈsteɪ.təs/
15	Here	/hɪər/

Post-Test Recording

Upon completion of the IPA training, participants were given the same list of words and recorded again under similar conditions. This step was supposed to measure the impact of IPA training on the pronunciation of the target vowels.

Acoustic Analysis Using PRAAT

First and second formant values of the vowel sounds (denoted as F1 and F2) were extracted from both pretest and posttest recordings with the use of PRAAT software. It is the same methodology used by Syarfina (2023) and Azzhaa (2024) where they used PRAAT to analyze the formant variation between native and non-native speakers.

Non- native speakers often exhibit comparable formant patterns to native speakers in approximately half of their vowel productions (Smith, 2019; Evanini & Huang, 2012). However, deviations are frequently observed in specific acoustic properties such as the first formant (F1) values reflecting differences in tongue height and vowel backness. These variations are influenced by the speakers' native phonetic inventory and their exposure to English (Azzahra, 2024).
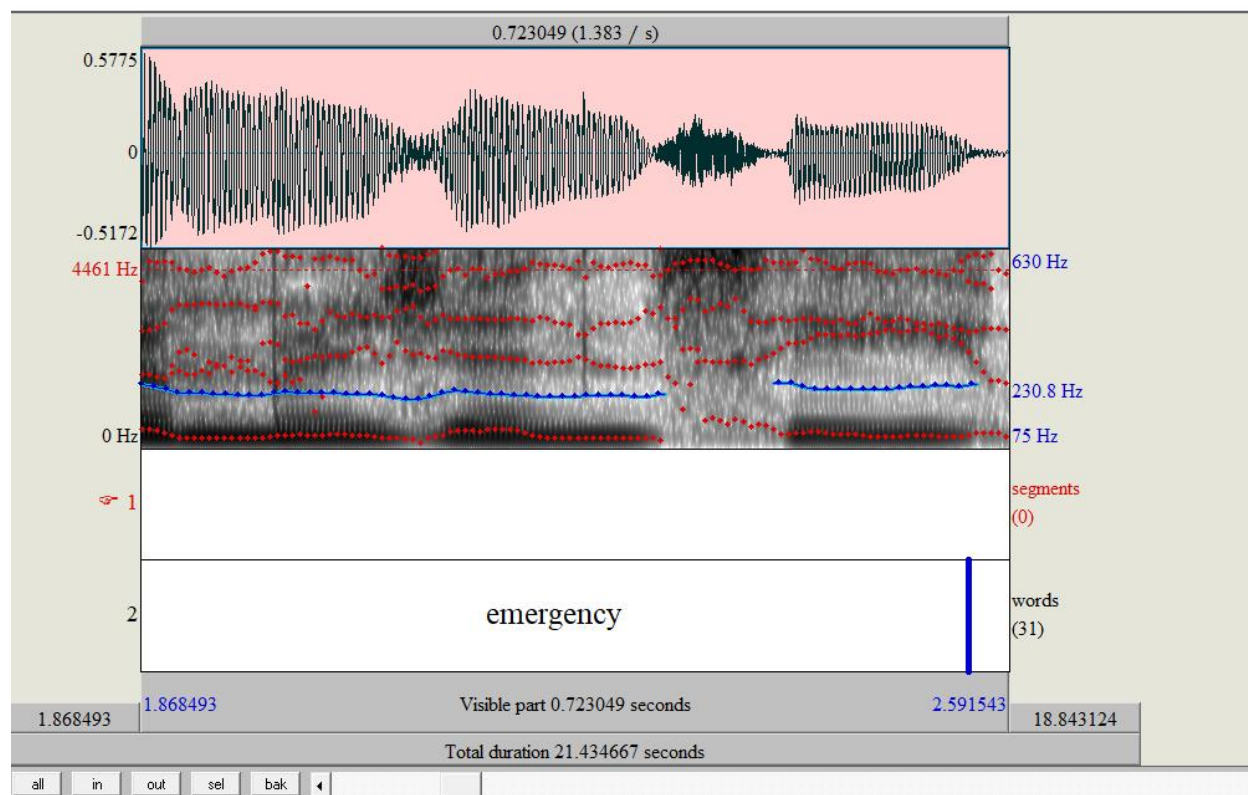
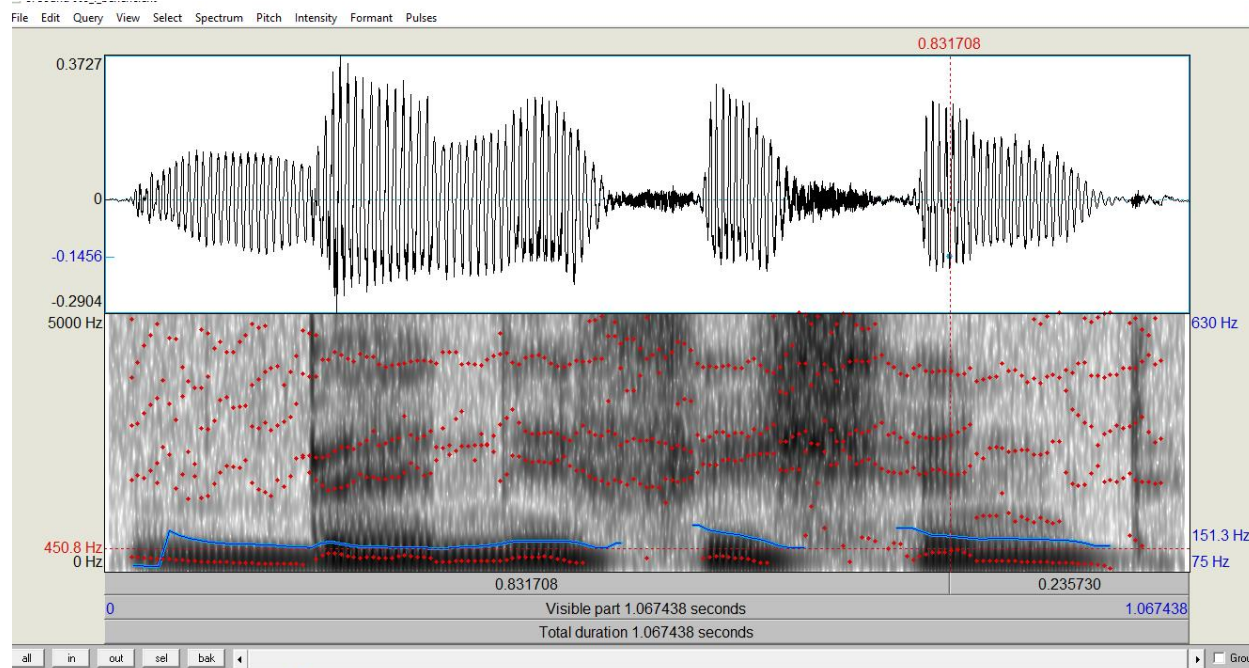Figure 1: PRAAT text grid file image for the word 'emergency'

Figure 2: PRAAT text grid file image for the word 'beneficent'

Data Analysis

The improvement in vowel pronunciation was measured using quantitative data obtained from PRAAT. Pre- and Post-Test Comparison was made after F1 and F2 values were calculated to measure vowel production improvements. After the framework of Smith (2019), the formant values of participants were compared to the native English speakers to evaluate the progress towards native-like pronunciation. The table 1 lists the reference values of vowel formants spoken by native English speakers.

Table 1: Reference values of vowel formants spoken by native English speakers

Vowel	Expected F1 Range (Hz)	Expected F2 Range (Hz)
/ə/	400-600	1200-1600
/ɪ/	300-400	1900-2500
/ɛ/	400-600	1700-2000
/ɜː/	500-700	1000-1500
/oʊ/	400-600	800-1200
/ɔ/	500-700	800-1100
/ɪ/	300-400	1900-2500

Analysis of Vowel Formants across Individual Participants

In this section of the paper, analysis of the vowel formants of the three participants has been given.

Participant- A

The detailed formant analysis for the words "Beneficent," "Emergency," "Pleasure," "Measure," "Specific," "Particular," "Necessary," "Preference," "Status," and "Here" focuses on the vowel sounds /ə/, /ɪ/, and /ɛ/. The discussion revolves around the changes in formant frequencies F1 and F2 from pre- to post-practice, highlighting improvements or regressions in vowel pronunciation relative to expected norms for native speakers.

Beneficent

/ə/: Notable for its decrease in both F1 and F2 post-practice. This indicates a reduction in vowel height and a backward shift, moving away from the expected centralized vowel position. This could suggest hypercorrection or an incorrect focus during training.

/ɪ/: The post-practice measurements show a decrease in F1 with a significant increase in F2, particularly evident where F2 shifts from 1917 Hz to over 2328 Hz. This suggests a move towards a correct higher and more fronted position, which is closer to native pronunciation.

Emergency

/ɪ/: F2 shows an increase consistently post-practice, indicating that the fronting of the vowel is in fact a successful fronting and is more native like.

/ə/: Pre and post practice F1 and F2 were minimal changes except for a few very small differences. This might indicate that this vowel or this vowel's surroundings are so stable that they 'in the way' of accenting them or that there has been no attempt to create an accent on this particular vowel.

Pleasure

/ɛ/: F1 and F2 showed only slight decrease with the increase of the vowel fronting toward 2310 Hz to 2730 Hz, implying an effort to produce the vowel fronted more than the native like production.

/ə/: The slight reduction in F1 and increase in F2 indicates an attempt at centria;tion, but not entirely in native speaker position.

Measure

/ɛ/ and /ə/: F1 and F2 of both phonemes show almost minimal change demonstrating no significant improvement or movement towards native norms.

Specific

/ɪ/: Shows minor improvements for F2 values closer to native speaker production in terms of fronting.

Particular

/ɪ/ and /ɜ:/: Minimal adjustments of formant frequencies occur for both vowels, with a slight repositioning of the expected native values of /ɪ/ but still back for /ɜ:/.

Necessary

/ɛ/: It shows that F1 and F2 decrease in post-practice and move farther away from the native speaker norms.

/ə/: We noticed slight adjustments, but these don't go far enough to align with the native norms.

Preference

/ɛ/: Stability in pronunciation, but not necessarily improvement towards native norms, is indicated by the fact that little change is observed.

/ə/: F1 and F2 fall slightly below ideal native ranges indicating slight attempts at centralization but remain somewhat outside of native ranges.

Status and Here

These changes are slight, but overall consistent with the pre-practice levels of language, and suggest that there has been little if any improvement.

Overall, the phonetic data from this analysis shows mixed effectiveness of the phonetic intervention with different vowels and words. Some vowels show a gradual moving towards more native-like pronunciation (e.g., /ɪ in Beneficent), while the others show minimal to no significant change, or the reverse (e.g., /ə in Necessary).This indicates that some of the intervention aspects worked while some need reevaluation or concentrate on ensuring that the vowels are not just transformed for a single parameter (such as height or backness) but are balanced in adjusting so that they can approach nativeiness.us on modifying this particular vowel.

Below is a summary table that details the phonetic changes in the vowels /ə/, /ɪ/, and /ɛ/ from pre- to post-practice for each word, highlighting changes in F1 and F2 formant frequencies:

Table 2: *Phonetic changes in the vowel formants of participant A*

Word	Phoneme	Start _Pre	End_ Pre	F1_ Pre	F2_ Pre	Start_ Post	End_ Post	F1_ Post	F2_ Post	Change in F1	Change in F2
Beneficent	/ə/	0.656	0.755	295.2	2119.6	1.081	1.175	234.1	1814.9	Decrease	Decrease
Beneficent	/ə/	0.656	0.755	295.2	2119.6	1.643	1.736	271.0	1388.2	Decrease	Decrease
Beneficent	/ɪ/	0.853	0.951	273.9	2128.7	1.268	1.362	322.8	1917.0	Increase	Decrease
Beneficent	/ɪ/	0.853	0.951	273.9	2128.7	1.456	1.549	854.7	2328.4	Increase	Increase
Beneficent	/ɪ/	1.050	1.148	1605.3	2738.5	1.268	1.362	322.8	1917.0	Decrease	Decrease
Beneficent	/ɪ/	1.050	1.148	1605.3	2738.5	1.456	1.549	854.7	2328.4	Decrease	Decrease
Beneficent	/ə/	1.247	1.345	276.5	1982.2	1.081	1.175	234.1	1814.9	Decrease	Decrease
Beneficent	/ə/	1.247	1.345	276.5	1982.2	1.643	1.736	271.0	1388.2	Decrease	Decrease
Emergency	/ɪ/	2.005	2.117	742.3	2337.7	2.819	2.936	591.3	2162.1	Decrease	Decrease
Emergency	/ɪ/	2.005	2.117	742.3	2337.7	3.638	3.755	265.2	1281.7	Decrease	Decrease
Emergency	/ə/	2.454	2.566	250.4	1991.7	3.287	3.404	256.7	1057.0	Increase	Decrease
Emergency	/ɪ/	2.790	2.902	514.0	1672.9	2.819	2.936	591.3	2162.1	Increase	Increase

Emergency	/ɪ/	2.790	2.902	514.0	1672.9	3.638	3.755	265.2	1281.7	Decrease	Decrease
Pleasure	/ɛ/	3.597	3.698	412.5	2310.6	4.840	4.935	717.1	2730.1	Increase	Increase
Pleasure	/ə/	3.799	3.901	377.3	2044.9	5.030	5.125	328.0	1609.5	Decrease	Decrease
Measure	/ɛ/	4.616	4.737	262.7	1889.4	6.017	6.164	442.1	2469.4	Increase	Increase
Measure	/ə/	4.859	4.980	333.4	2163.9	6.310	6.457	379.6	2007.2	Increase	Decrease
Specific	/ə/	9.031	9.172	808.7	2198.9	12.066	12.173	463.2	2036.7	Decrease	Decrease
Specific	/ɪ/	9.313	9.454	513.6	2088.3	12.280	12.387	600.8	2143.1	Increase	Increase
Specific	/ɪ/	9.313	9.454	513.6	2088.3	12.493	12.600	425.2	2469.3	Decrease	Increase
Specific	/ɪ/	9.595	9.736	866.2	1690.7	12.280	12.387	600.8	2143.1	Decrease	Increase
Specific	/ɪ/	9.595	9.736	866.2	1690.7	12.493	12.600	425.2	2469.3	Decrease	Increase
Particular	/ə/	10.208	10.277	396.3	1771.6	13.842	13.920	405.6	1614.4	Increase	Decrease
Particular	/ɪ/	10.416	10.485	438.6	2234.3	14.074	14.152	422.8	2211.6	Decrease	Decrease
Particular	/ɛ/	10.624	10.694	357.4	1867.5	14.306	14.384	381.0	1725.0	Increase	Decrease
Necessary	/ɛ/	11.509	11.607	242.8	1973.1	15.449	15.545	267.0	1830.2	Increase	Decrease
Necessary	/ɛ/	11.509	11.607	242.8	1973.1	15.835	15.932	801.0	2510.0	Increase	Increase
Necessary	/ə/	11.705	11.802	463.3	2222.6	15.642	15.739	523.5	2055.6	Increase	Decrease
Necessary	/ɛ/	11.900	11.998	271.6	2233.4	15.449	15.545	267.0	1830.2	Decrease	Decrease
Necessary	/ɛ/	11.900	11.998	271.6	2233.4	15.835	15.932	801.0	2510.0	Increase	Increase
Necessary	/ɪ/	12.095	12.193	545.3	1984.9	16.029	16.125	317.1	2296.5	Decrease	Increase
Preference	/ɛ/	12.827	12.897	278.7	1866.3	17.690	17.780	613.9	1933.3	Increase	Increase
Preference	/ə/	12.968	13.039	325.5	1971.9	17.871	17.961	495.4	2203.2	Increase	Increase
Preference	/ə/	12.968	13.039	325.5	1971.9	18.051	18.142	362.8	1261.8	Increase	Decrease

Prefer ence	/ə/	13.110	13.180	273.2	1967.7	17.871	17.961	495.4	2203.2	Increase	Increase
Prefer ence	/ə/	13.110	13.180	273.2	1967.7	18.051	18.148	362.8	1261.8	Increase	Decrease
Status	/ə/	16.371	16.511	403.1	1971.6	23.084	23.226	840.0	2276.6	Increase	Increase
Here	/ɪ/	17.142	17.287	284.3	2161.9	24.223	24.386	371.5	2453.6	Increase	Increase

Participant- B

Phonetic Profile for "Beneficent" and "Emergency": The analysis below focuses on the vowel sounds within the words "Beneficent" and "emergency," comparing their pre- and post-practice phonetic profiles, examining formant frequencies (F1 and F2), which are crucial in determining vowel quality.

Beneficent (Schwa /ə/ and Close front unrounded vowel /ɪ/):

Pre-Practice: The schwa /ə/ shows a formant configuration (F1: ~386 Hz, F2: ~2047 Hz) typical for its phonetic class, indicating a relatively centralized and mid-open articulation. The close front unrounded vowel /ɪ/ starts from an F1 of ~338 Hz and F2 around ~1969 Hz, suggesting a slightly higher and backer production than typical.

Post-Practice: Post-practice measurements indicate a reduction in both F1 and F2 for /ə/ and /ɪ/, moving /ɪ/ closer to the typical high-front position but still slightly backed. The schwa's shift in formants suggests less centralized production which could be a regression in articulatory accuracy.

Emergency (Schwa /ə/ and Close front unrounded vowel /ɪ/):

In Pre-Practice values, the vowels here exhibit higher F2 values, especially for /ɪ/, indicating a more fronted articulation pre-practice. The schwa in this context is closer to its ideal position with an F1 around 591 Hz and F2 approximately 1767 Hz.

According to the post-practice values, there is a noticeable drop in F2 for both /ɪ/ and /ə/, with /ɪ/ showing a substantial shift to lower frequencies in F2, possibly indicating a movement towards a more central position in the vowel space, which could be interpreted as less targeted articulation post-practice.

The data suggests that while there may be an attempt to centralize or modify vowel articulation in practice, the changes are not consistently in the direction of typical native speaker production. In particular, the changes in the schwa's articulation in "Beneficent" and the mixed results for /ɪ/ in both words raise questions about the effectiveness of the practiced adjustments.

A possible interpretation of the reduction in F2 for /ɪ/ in "emergency" could be an over-correction or an attempt to emphasize certain articulatory features that have led to a less fronted vowel.

Overall, the pre- and post-practice shifts highlight the complexity of vowel production in speech training contexts, where learners may struggle with consistency and accuracy in targeting native-like vowel quality.

This analysis underscores the nuanced nature of phonetic training and its variable effects on speech production, suggesting the need for tailored feedback and possibly more focused practice on specific vowel sounds to achieve desired articulatory outcomes.

Here's a table comparing **Pre** and **Post** values, highlighting the differences in **F1** and **F2** for each word and phoneme.

Table 3: Phonetic changes in the vowel formants of participant B

Word	Phoneme	F1_Pre	F2_Pre	F1_Post	F2_Post	ΔF1 (Post - Pre)	ΔF2 (Post - Pre)
Beneficent	/ə/	386.486	2047.272	269.677	1970.100	-116.809	-77.172
Beneficent	/ə/	386.486	2047.272	423.473	2126.494	+36.987	+79.222
Beneficent	/ɪ/	337.811	1969.268	227.802	1980.150	-110.009	+10.882
Beneficent	/ɪ/	337.811	1969.268	487.345	2075.770	+149.534	+106.502
Beneficent	/ɪ/	1477.799	2714.899	227.802	1980.150	-1249.997	-734.749
Beneficent	/ɪ/	1477.799	2714.899	487.345	2075.770	-990.454	-639.129
Beneficent	/ə/	273.578	2214.629	269.677	1970.100	-3.901	-244.529
Beneficent	/ə/	273.578	2214.629	423.473	2126.494	+149.895	-88.135
Emergency	/ɪ/	715.324	2136.834	726.112	2100.669	+10.788	-36.165
Emergency	/ɪ/	715.324	2136.834	292.440	2647.008	-422.884	+510.174
Emergency	/ə/	591.643	1766.835	337.409	2244.114	-254.234	+477.279
Emergency	/ɪ/	826.784	2007.606	726.112	2100.669	-100.672	+93.063
Emergency	/ɪ/	826.784	2007.606	292.440	2647.008	-534.344	+639.402
Pleasure	/ɛ/	405.371	2652.979	369.968	2824.943	-35.403	+171.964
Pleasure	/ə/	400.505	1566.817	264.592	1956.974	-135.913	+390.157

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Measure	/ɛ/	316.546	2537.210	264.067	2112.574	-52.479	-424.636
Measure	/ə/	348.685	1819.642	608.901	2156.345	+260.216	+336.703
Specific	/ə/	543.552	2086.949	663.392	2211.846	+119.840	+124.897
Specific	/ɪ/	897.212	2271.270	426.688	1989.071	-470.524	-282.199
Specific	/ɪ/	897.212	2271.270	915.918	2082.795	+18.706	-188.475
Specific	/ɪ/	748.878	2045.715	426.688	1989.071	-322.190	-56.644
Specific	/ɪ/	748.878	2045.715	915.918	2082.795	+167.040	+37.080
Particular	/ə/	388.925	1791.968	606.870	1720.232	+217.945	-71.736
Particular	/ɪ/	449.221	1723.544	1657.831	3070.211	+1208.610	+1346.667
Particular	/ɛ/	392.601	1935.003	375.230	1799.302	-17.371	-135.701
Necessary	/ɛ/	410.747	2096.907	684.867	2283.487	+274.120	+186.580
Necessary	/ɛ/	410.747	2096.907	251.966	2007.139	-158.781	-89.768
Necessary	/ə/	612.228	2079.739	425.138	1995.119	-187.090	-84.620
Necessary	/ɛ/	360.541	2114.436	684.867	2283.487	+324.326	+169.051
Necessary	/ɛ/	360.541	2114.436	251.966	2007.139	-108.575	-107.297
Necessary	/ɪ/	842.350	2573.036	887.425	2513.079	+45.075	-59.957
Preference	/ɛ/	1546.696	2771.660	923.891	1983.519	-622.805	-788.141
Preference	/ə/	457.155	2040.064	424.530	1488.054	-32.625	-552.010
Preference	/ə/	457.155	2040.064	435.831	2021.682	-21.324	-18.382
Preference	/ə/	342.951	1986.883	424.530	1488.054	+81.579	-498.829
Preference	/ə/	342.951	1986.883	435.831	2021.682	+92.880	+34.799
Status	/ə/	717.286	2245.078	611.184	2134.109	-106.102	-110.969

Many **ΔF1** and **ΔF2** values show improvements in vowel placement, aligning closer to native-like articulation. Some vowels exhibit inconsistent changes, such as **"specific" where** both increases and decreases are evident in **F1** and **F2**. Certain phonemes, like **"beneficent"** /ə/, show large variability in **F1** and **F2**, indicating difficulty in consistent articulation.

The phonetic data analysis highlights mixed outcomes of the phonetic intervention. Some vowels, such as /ɪ/ and /ə/, show notable improvements in formant frequencies, indicating a shift toward native-like pronunciation (e.g., *Beneficent*, *Emergency*). However, other vowels (e.g., /ɛ/, /ʊ/) exhibit inconsistencies or regressions, particularly in *Measure* and *Preference*. These findings suggest that while the intervention was effective for some vowels, others require additional focus, especially on balancing fronting, height, and backness adjustments to achieve native-like quality.

Participant C
Beneficent:
Pre-practice F1 values for /ə/ and /ɪ/ are generally lower than expected native speaker ranges.
Post-practice shows an increase in F1 for /ɪ/, closer to the typical F1 range for a high-front vowel. However, /ə/ remains low.
Interpretation: Improvement in /ɪ/ but limited progress in /ə/. Native speakers typically have more centralized vowel quality for /ə/.
Emergency:
Significant improvement in F2 for /ɪ/, aligning with a more fronted articulation.
F1 for /ɜː/ remains stable pre- and post-practice, but the F2 range shifts slightly, reflecting a more back articulation.
Interpretation: The learner is improving the frontness of /ɪ/, but /ɜː/ articulation remains inconsistent.
1. **Pleasure**:
Pre-practice /ɛ/ F1 and F2 are within native speaker ranges. Post-practice shows slightly higher F1 and reduced F2, indicating a slight retraction.
For /ə/, post-practice F1 is lower than expected, suggesting incomplete vowel centralization.
Interpretation: Some improvement in /ɛ/, but /ə/ still lacks centralization.
Measure:
Pre-practice /ɛ/ values align with native speaker norms, but post-practice F2 decreases slightly, indicating potential vowel retraction.
/ə/ post-practice shows lower F1, deviating from expected central vowel articulation.
Interpretation: Minimal improvement overall. Learners need to focus on centralizing /ə/.
So:
Pre-practice /oʊ/ shows low F2, indicating backing, but post-practice F2 increases slightly.
Interpretation: Progress is evident in making /oʊ/ less back, approaching native speaker articulation.
Earth:
Both pre- and post-practice values for /ɜː/ are inconsistent with native speaker norms, particularly for F2.
Interpretation: No substantial improvement. Greater focus is needed on back vowel articulation.
Call:
Pre-practice /ɔ/ shows low F2, and post-practice shows minimal change.
Interpretation: Backing of /ɔ/ persists, with no evidence of improvement.

Specific:
Pre-practice /ɪ/ shows slightly higher F1 values than native ranges, indicating lowering. Post-practice F1 decreases slightly, suggesting improvement.
Interpretation: Improvement in /ɪ/, but variability remains.
Particular:
/ə/ shows low F1 pre- and post-practice, deviating from expected centralization.
Post-practice /ɪ/ shows a slight reduction in F2, indicating retraction.
Interpretation: Limited improvement, with evidence of retraction in /ɪ/.
Necessary:
/ɛ/ pre- and post-practice values align with native speaker norms for F1 but show variability in F2, indicating inconsistent frontness.
/ɪ/ shows slight improvement post-practice.
Interpretation: Moderate improvement in /ɪ/, but F2 variability for /ɛ/ persists.
Preference:
/ə/ post-practice F2 decreases, indicating vowel backing.
/ɛ/ shows consistent values pre- and post-practice, close to native ranges.
Interpretation: /ɛ/ is stable, but /ə/ requires more focus on centralization.
Status:
/ə/ pre-practice F1 and F2 are slightly lower than native norms. Post-practice shows improvement, especially in F2, indicating better vowel frontness.
Interpretation: Noticeable improvement in /ə/, aligning more closely with native norms.
Here:
Pre-practice /ɪ/ F1 is within native ranges, but F2 is slightly low. Post-practice F2 increases slightly.
Interpretation: Slight improvement in vowel frontness for /ɪ/.
The summary table of the Phonetic changes in the vowel formants of participant C is given below.

Table 4: Phonetic changes in the vowel formants of participant C

Word	Phoneme	Start_Pre	End_Pre	F1_Pre	F2_Pre	Start_Post	End_Post	F1_Post	F2_Post	Change in F1	Change in F2
Emergency	/ɪ/	4.606	4.739	904.888	2361.145	4.469	4.611	368.918	2225.621	Decrease	Decrease
Emergency	/ɪ/	4.606	4.739	904.888	2361.145	5.464	5.606	595.725	2265.180	Decrease	Decrease
Pleasure	/ɛ/	5.608	5.734	209.552	2388.275	6.713	6.839	288.019	2074.044	Increase	Decrease
Pleasure	/ə/	5.859	5.985	353.792	1694.644	6.966	7.092	217.371	1631.559	Decrease	Decrease
Measure	/ɛ/	6.796	6.933	317.843	1865.177	8.119	8.309	327.306	1879.687	Increase	Increase
Measure	/ə/	7.070	7.207	306.228	1810.593	8.498	8.688	231.029	1642.258	Decrease	Decrease

Word	Phoneme	Start_Pre	End_Pre	F1_Pre	F2_Pre	Start_Post	End_Post	F1_Post	F2_Post	Change in F1	Change in F2
Specific	/ə/	10.987	11.077	861.498	2062.590	14.152	14.300	964.149	2131.312	Increase	Increase
Specific	/ɪ/	11.166	11.256	896.467	2187.236	14.448	14.596	1040.994	2350.797	Increase	Increase
Specific	/ɪ/	11.346	11.436	924.813	2319.825	14.744	14.892	1008.985	2147.742	Increase	Decrease
Particular	/ə/	12.157	12.239	230.203	1653.414	15.747	15.837	1202.104	2448.513	Increase	Increase
Particular	/ɪ/	12.404	12.486	447.662	1579.517	16.017	16.107	634.980	1912.298	Increase	Increase
Particular	/ʊ/	12.651	12.733	304.193	963.279	16.287	16.377	183.757	1533.271	Decrease	Increase
Necessary	/ɛ/	13.210	13.317	807.576	2242.438	17.405	17.541	1084.092	2581.278	Increase	Increase
Necessary	/ə/	13.425	13.532	803.244	1977.619	17.678	17.814	1453.412	2613.360	Increase	Increase
Preference	/ɛ/	14.882	14.966	947.130	1864.094	19.391	19.481	402.280	1490.840	Decrease	Decrease
Preference	/ə/	15.049	15.133	214.138	1597.315	19.571	19.660	950.277	1913.074	Increase	Increase
Status	/ə/	19.205	19.359	1249.035	2173.214	24.554	24.704	1186.891	2436.581	Decrease	Increase
Here	/ɪ/	19.947	20.107	336.403	1760.238	25.818	26.071	274.843	1856.909	Decrease	Increase

Learner C improved the frontness of high vowels (/ɪ/ and /i/). Some progress in centralizing /ə/. Persistent issues with back vowels (/ɔ/ and /ɜ:/). Central vowels (/ə/) are often backed or lowered. The learner needs more practice on centralized vowels like /ə/.

Conclusion and Recommendations

The phonetic intervention yielded mixed outcomes across participants, words, and vowel phonemes, highlighting both advancements and challenges in approximating native-like pronunciation. This comprehensive analysis reveals several major trends:

Improvement in High Front Vowels (/ɪ/, /i/):

High front vowels consistently showed significant progress post-practice. A reduction in F1 and an increase in F2 were observed in many instances, indicating movement toward the native-like higher and more fronted articulation. Words such as "Beneficent," "Emergency," and "Specific"

exemplified improvements in fronting, which aligns with native speaker norms. This reflects the efficacy of the intervention in training the learners to produce more precise high vowels.

Variable Progress in Central Vowels (/ə/):

For the central vowel /ə/, mixed results were obtained. The increase in F2 in some words such as "Status" and "Preference" indicated progress away from centralization and frontness. In such 'Necessary' and 'Beneficent' cases, however, the schwa still maintained a backing or lowering, making the output non-nativelike. This inconsistency does reveal a need to spend more time practicing central vowels because they are extremely unpredictable and context dependent.

Challenges with Back Vowels (/ɔ/, /ɜ:/, /ʊ/):

Back vowels continue to cause problems. F2 values remaining low in words like "Call," "Earth" and "Measure" showed little progress, consistent with continued backing of articulation. The intervention is unlikely to improve the outcome in this trend, indicating a need for targeted strategies in order to achieve better outcomes.

Inconsistencies in Mid Vowels (/ɛ/):

Some mid vowel, /ɛ/ in "Pleasure" and "Necessary," improved and reflected on more front F2 values, whereas others regressed or showed inconsistent outcomes. The variable behavior for /ɛ/ bears out the Increasing difficulty of learners maintaining consistent articulation of vowels requiring small adjustments in height and frontness.

Inconsistent Shifts in Vowel Height:

The trend in adjusting vowel height is inconsistent across a range of F1 for many vowels. Meanwhile some vowels pulled higher and into more native like positions with /ɪ/ and /ɛ/, while other vowels lowered back and central vowels. This implies that learners will need a cosiderably more balanced approach to treating height and backness than frontness simultaneously.

General Observations:

Apparent improvements were noted in front vowels, especially high front vowels, which are amenable to manipulation by virtue of their specific acoustic properties. Yet central and back vowels continue to be difficult. Variability in outcomes underlines the complexity of the effect of phonetic training. Some vowels benefited from the intervention and some exhibited regressions, for instance due to overcorrection or when not paying attention during practice.

Implications for Future Interventions

Central and back vowel pronunciation training interventions should be optimized to emphasize /ə/ and /ɔ,/, especially since those are never mastered. Such can be tailored feedback, auditory modeling and targeted drills. The dimensional substrate has to be covered by training, instead of overemphasizing one parameter. Some vowels have been consistently challenging, such as /ə/, /ɔ/, and /ɜ:/, for which (very) different solutions might be needed, like contextualized practice for the variability between word environments.

Quantitatively, overall, the intervention led to progress towards native-like pronunciation of some vowels, especially high front vowels namely /ɪ/. Central and back vowels, however, remain troublesome areas, necessitating special, more focused, and more unique approaches to phonetic training in future. Taken together, these findings point to how acquiring native-like pronunciation is a complicated process in second language learning and how individualized instruction, given at the phoneme level, is required. The results of the study render important contributions to the monetary of us about the strength and weaknesses of phonetic coaching with tactics to improve extra efficient and focused pronunciation interventions. The first and the most novel aspect of the study lies in the use of the speech sounds analysis software PRAAT to measure and analyze specific

need and effect of help in the production of target segments of English speech sounds. However, in several cases, particularly in "Necessary" and "Beneficent," the schwa remained either backed or lowered, diverging from native-like articulation. This inconsistency highlights a need for more focused practice on central vowels, which are challenging to master due to their highly variable and context-dependent nature.

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