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Contrastive Analysis of Acoustic Vowel Space: Standard Sri Lankan English, Standard Southern British pronunciation of English and Sinhala

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Abstract: This paper presents findings of an acoustic phonetic analysis of eleven monophthongal phonetic vowels produced by bilingual speakers from Sri Lanka with Standard Sri Lankan English (SSLE) and Sinhala in their code repertoire. The instrument for English elicitations consists of 22 word tokens where each vowel is produced in /hVd/ and /bVt/ frames. The instrument for Sinhala elicitations marginally deviates and includes 10 disyllabic tokens due to language specific restrictions but the word initial clusters of /hV-/ and /bV-/ were retained. The methodology recorded vowel productions of 10 male and 10 female neurologically normal speakers and acoustic phonetic analyses of mean vowel formant frequencies were performed using the Bark psycho-acoustical scale. The findings were then compared with Mean Formant frequencies of monophthong vowels of Standard Southern British pronunciation of English (SSBE) recorded in literature. Cross-linguistic variation in the vowels in the vowel space across SSBE and SSLE was analyzed through plotted vowel quadrilaterals. This study also presents some new results, previously not noted in the literature on SSLE, particularly with respect to vowel space quadrilateral construction of its phonology.
Keywords: speech analysis, vowels, SSBE, SSLE.

INTRODUCTION
Background

Pronunciation, as far back as in 1969 was labelled by Kelly [1] as 'the Cinderella of language teaching' (p. 87). Kelly's metaphor of pronunciation as the *Cinderella of language teaching* according to Brinton [2] implies that, traditionally, pronunciation has been neglected in the language classroom and that its rightful place is at the forefront of instruction, along with the four skills, grammar and vocabulary. Highlighting the importance of pronunciation Fraser [3] contends that 'with good pronunciation, a speaker is intelligible despite other errors; with poor pronunciation, a speaker can be very difficult to understand despite accuracy in other areas. Pronunciation is the aspect that most affects how the speaker is judged by others, and how they are formally assessed in other skills' (p. 7). Yet as recent as in 2010 Derwing [4] has noticed that 'L2 teachers are somewhat intimidated by the idea of teaching pronunciation' (p. 24) and Gilbert [5] still assigns pronunciation the rank of 'an orphan' in English language classrooms around the world.

Pronunciation research and pedagogy identifies two tenets: the nativeness principle and the intelligibility principle Morley [6]. Nativeness principle which according to Levis[8] 'was the dominant paradigm in pronunciation teaching before the 1960s, holds that it is both possible and desirable to achieve native-like pronunciation in a foreign language'. The intelligibility principle (ibid: 371) states that 'different features have different effects on understanding. Instruction should focus on those features that are most helpful for understanding and should deemphasize those that are relatively unhelpful'.

Abercrombie's [8] claim that most language learners "need no more than a comfortably intelligible pronunciation [...] which can be understood with little or no conscious effort on the part of the listener" still gains agreement from most scholars. Afshari & Ketabi [9] too consider intelligibility (ability to make oneself relatively easily understood) as one of the most important issues and communicative efficiency rather than nativeness or perfect pronunciation is the target of teaching pronunciation. But they caution that an internationally acceptable level of intelligibility is the desired objective. Agreement comes from Gilbert [10] who argue that 'the goal of pronunciation instruction is not helping students to sound like native speakers but as helping them to learn the core elements of spoken English so that they can be easily understood by others. In other words, teachers and students can overcome the frustrations, difficulties, and boredom often associated with pronunciation by focusing their attention on the development of pronunciation that is ‘listener friendly’. (p. 1)

Many pedagogical views in the area of pronunciation ascertain that attention to segmentals is needed first, and then suprasegmentals. Derwing & Munro [11] state that segmental errors can sometimes preclude full intelligibility of speech. Of the segmentals according to Ladefoged [12] ‘accents of English differ more in their use of vowels than in their use of consonants’. Thus this study aims to identify the differences in the vowel spaces of SSBE and SSLE. It further attempts to investigate whether the vowel phonology of Sinhala, the other language along with SSLE in the participant population, had influenced the shifting of the vowel space.

Vowels of SSBE, SSLE and Sinhala

Linguists are in agreement that English has 11 phonemic monophthongs [13]; Ladefoged [12]. SBE and SSLE have a close affinity with respect to their phonemic inventory of simple vowels. But the SSLE sound system according to Widyalankara [14] shows a strong influence of Sinhala in the articulation of Sinhala/SSLE (L1 and L2 respectively) bilinguals. Major [15] too theorizes that the L2 sound system is influenced to varying degrees by the sound system of the L1. Further Flege’s [16] Speech Learning Model (SLM) postulates that ‘Bilinguals strive to maintain contrast between L1 and L2 phonetic categories, which exist in a common phonological space’ and forms 7 Hypotheses on this aspect.

Flege’s Hypothesis 1 in SLM (ibid: 239) states that ‘sounds in the L1 and L2 are related perceptually to one another at a position-sensitive allophonic level, rather than at a more abstract phonemic level’. Hypothesis 6 states that the phonetic category established for L2 sounds by a bilingual may differ from a monolingual's if: 1) the bilingual's category is ‘deflected’ away from an L1 category to maintain phonetic contrast between categories in a common Ll-L2 phonological space; or 2) the bilingual's representation is based on different features, or feature weights, than a monolingual's. The *perceptual magnet hypothesis* [17] too proposes that non-native speakers tend to ‘attract’ phonemes in their L2 to standard exemplar phonemes in their first language (L1). Striving to examine the above hypotheses in the context of this study the table below showcases the similarities as well as the contrasts between the vowel phonology of SSBE (RP), SSLE and Sinhala.

Table-1: Contrasting the vowel inventories of RP, SSLE, Sinhala [14]

RP Roach (2004: 243)	SSLE Gunesekera (2005: 117)	Sinhala Wasala & Gamage (2005: 474)
ɪ	ɪ	
	ɪɪ	
	i	i
i:	ii	i:
	u	u
u:	uu	u:
ʊ	ʊ	
	e	e
	ee	e:
	o	o
	oo	o:
ɛ	ɛ	
	ɛɛ	
ə	ə	ə
	əə	ə:
ɜ:		
ɒ	ɔ	
ɔ:	ɔɔ	
æ	æ	æ
	ææ	æ:
ʌ	ʌ	
	ʌʌ	
	ɑ	ɑ
ɑ:	ɑ:	ɑ:

As illustrated in the above table the three languages SBE, SSLE and Sinhala have a multitude of shared vowels which are represented by common phonemic symbols. But literature on vowel production by bilingual speakers [18]; Chung *et al*. [19]; Yang [20] indicate that there are systematic, subtle cross-linguistic formant pattern differences between shared vowels. Additionally there is asymmetry in the presence/absence of selected vowels as illustrated in the table below which are of special interest to this study.

Table-2: Asymmetry in selected vowels SSBE, SSLE and Sinhala

SSBE Deterding [21]	SSLE Gunesekera [22]	Sinhala Wasala, Gamage [23]
	o	o:
	o:	o:
/ɜ:/	/ɜ:/	
/ɒ/	/ɔ/	
/ɔ:/	/ɔ:/	
/ʌ/	/ʌ/	
/ʌ:/	/ʌ:/	

In this paper an instrumental phonetic analysis of F1 and F2 formants of selected vowels is conducted and vowel space illustrations provide the contrast. Vowel Space Area (VSA) according to Sandoval *et al*. [24] refers to the two-dimensional area bounded by lines connecting first and second formant frequency coordinates ($F1/F2$) of vowels is an attractive metric for the study of speech production deficits and reductions in intelligibility. The vowel space illustration provides a graphical method of showing where a speech sound, such as a vowel, is located in both acoustic and articulatory space. Within an articulatory space $F1$ and $F2$ formants of vowels indicate different characteristics of a vowel.

Comparison of vowel formants

Hayes [25], Kent [26], O'Connor [27] and Styler [28] set down the following as general rules of vowel formants:

- A close vowel and an open vowel, respectively describe the jaw as open or closed. Vowel height is inversely correlated to F1 thus higher the F1 value, the lower (more open) the vowel.
- F2 denotes the frontness of the vowel. Back vowels have low F2 frequencies while front vowels have high F2 frequencies.
- F3 indicates the exolabial quality of a vowel. Catford [29] states that exolabial rounding involves vertical compression of the corners of the mouth, 'leaving a small central channel between the lips, of a slit-like flat elliptical shape rather than actually round.This gesture is exolabial since it involves the outer surface of the lips'. Ladefoged[30] suggest that 'usually front vowels are more rounded than back vowels and the higher a back vowel is, the more intense the rounding. According to Ladefoged [12] 'lip rounding is generally characterized by the lowering of the second and third formants. Catford [29]

METHODOLOGY

Research question

Do speakers of SSLE allocate the same vowel space as speakers of SSBE do when producing English vowels?

Instruments

Small [31] states that the consonant /h/ is one of the most suited for vowel elicitations as during its production 'the articulators will take the shape of whichever vowel follows'. The instruments of this study produced elicitations in /hVd/ and /bVt/ frames for SSLE and the Sinhala elicitations include a few disyllabic tokens but the word initial clusters of /hV-/ and /bV-/ were retained.

Table-3: Instrument I- Tokens for English word elicitations by Sinhala/ SSLE bilinguals

#	Word	Vowel	#	Word	Vowel
1	heed	/i:/	12	bought	/ɔ:/
2	beat	/i:/	13	hoed	/o:/(BE/əʊ/)
3	hid	/ɪ/	14	boat	/o:/(BE/əʊ/)
4	bit	/ɪ/	15	hood	/ʊ/
5	hayed	/e:/(BE/eɪ/)	16	book	/ʊ/
6	bait	/e:/(BE/eɪ/)	17	who'd	/u:/
7	head	/e/	18	boot	/u:/
8	bet	/e/	19	hudd	/ʌ/
9	had	/æ/	20	but	/ʌ/
10	bat	/æ/	21	heard	/ɜ:/
11	hod	/ɒ/	22	bird	/ɜ:/

It is to be noted that in SSLE pronunciation the SSBE diphthongs /ei/ and /əʊ/ emerge as /e:/ and /o:/ respectively. Thus the recordings will be analyzed for the vowels /e:/ in the words *hayed* and *bait*. The emerging /o:/ of the word tokens *hoed* and *boat* too will undergo analysis for formant values.

Table-4: Instrument II- Tokens for Sinhala word elicitations by Sinhala/ SSLE bilinguals

	Vowel	Word	IPA	Sinhala word
1	/i:/	*hiinə*	/hi:nə/	හීන
2	/i:/	*biiri*	/bi:ri /	බීරි
3	/ɪ/	*his*	/hɪsə/	හිස
4	/ɪ/	*bilə*	/bɪlə/	බිල
5	/æ/	*barə*	/bærə/	බැර
6	/æ/	*hadə*	/hædə/	හැඩ
7	/a:/	*haanə*	/ha:nə/	හාන
8	/a:/	*baanə*	/ba:nə/	බාන
9	/o:/	*hoora*	/ho:ra:/	හෝරා
10	/o:/	*boorə*	/bo:rə/	බෝර

A total of 32 tokens for vowel categories in each language were recorded in a sound proof booth at the University of Kelaniya. The population consisted of 10 male and 10 female bilingual speakers with SSLE and Sinhala in their code repertoire.

Praat speech processing software [32] was used for recording the elicitations of the word tokens. Recordings were made on a laptop computer and the subjects were seated in a sound proof room a few centimeters away from a head-mounted micro-phone. They were asked to read a list of monosyllabic English words which included all the target English vowels (Instrument I, Table 3). Then the pronunciation of the ten Sinhala words in Instrument II, Table 4 was recorded for all participants. Formant tracks were automatically computed for the lowest three formants (F1, F2, F3). The frequency range was 0 - 4000 Hz. The formant values were extracted from the spectrograms at the midpoint of every vowel using formant tracking. This was done as Ladefoged and Maddieson [33] endorse that the vowel formants should be obtained at the midpoint so as to minimize the effects of the preceding or the following consonant on the target vowel.

This study plots the formants in a Vowel Space Area (VSA) which refers to the two-dimensional area bounded by lines connecting first and second formant frequency coordinates (F1/F2) of vowels. VSA according to Fant [34] is a metric for the study of speech production and reductions in intelligibility.

The control group

English was introduced to Sri Lanka during the British colonial period and it originated from the British standard during colonial times. Thus British English could be considered as the initial donor language in the context of SSLE. Selecting the current users of the standard for British pronunciation this study first cites Vowel quadrilaterals for the monophthongs of British English [35] given below as a reference point.

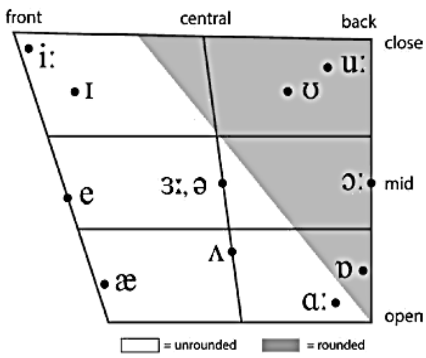

Fig-1: Vowel quadrilaterals for the monophthongs of British English [35]

Secondly for the purpose of contrastive analysis this study elects to use the vowel formants of SSBE. Thus a control group of native speakers of SSBE were obtained from the data published by Deterding [36] which provide the formant measurements of the eleven monophthong vowels recorded by five male and five female BBC broadcasters. The data contains the measurements of the first 3 formants of the 11 monophthong vowels. Though Ladefoged [12] identifies the height and backness is acoustically the most relevant parameters in describing vowels in world languages this study extends its formant measurements to F1, F2 and F3. This is as it wishes to include F3 as a measure for the exolabial quality of vowels in its contrastive analysis.

Table-5: Average values in Hz. [36]

	Male			Female		
	F_1	F_2	F_3	F_1	F_2	F_3
iː	280	2249	2765	303	2654	3203
ɪ	367	1757	2556	384	2174	2962
e	494	1650	2547	719	2063	2997
æ	690	1550	2463	1018	1799	2869
ʌ	644	1259	2551	914	1459	2831
ɑː	646	1155	2490	910	1316	2841
ɒ	558	1047	2481	751	1215	2790
ɔː	415	828	2619	389	888	2796
ʊ	379	1173	2445	410	1340	2697
uː	316	1191	2408	328	1437	2674
ɜː	478	1436	2488	606	1695	2839

Discussing non-uniform scaling between male and female vowels Diehl *et al*. [37] state that this is due to adult female vocal tracts being shorter than those of adult males. This they claim, leads to higher frequencies for female formants. This non-uniform between formant values of male and female vowels is very much evidenced in the average values of F1and F2 tabulated above (Table 5) by Deterding [36]. Based on the average values of F1and F2 Deterding [36] plots the following vowel quadrilateral for male and female native speakers of SSBE.

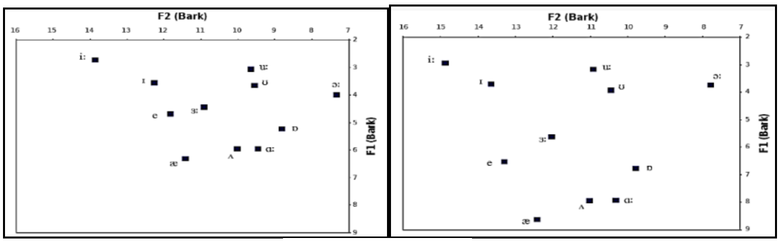

Fig-3: Female speakers of SSBE

For the purpose of contrastive analysis the formant values in Table 4 were used to calculate the average formant values were for SSBE and are tabled below.

Table-6: Average formant values for SSBE

SSBE			
Vowel	F1	F2	F3
iː	432	2452	2984
I	376	1966	2759
e	607	1857	2772
æ	1120	1409	2666
ʌ	779	1359	2691
ɑː	778	1236	2666
ɒ	655	1131	2636
ɔː	402	858	2708
ʊ	395	1257	2571
uː	322	1314	2541
ɜː	542	1566	2664

According to Brett [38] a vowel normalization is utilized to compensate for speaker-specific differences in vocal-tract size, But a 'possible side effect of the normalization process is that it can reduce legitimate differences between vowel formants and in some cases suggest differences that did not exist in the original data' [39]. Thus this study uses un-normalized vowel formants from participants to investigate the acoustic properties of the 12 vowels found in word-medial position in 22 word tokens.

Following Deterding [36] un-normalized vowel formants of the word tokens is converted to values along a Bark scale. Bark is a psycho-acoustical scale proposed by [40] and according to Smith and Abel [41] Bark units represent samplings of a continuous variation in the frequency response of the ear to a sinusoid or narrow band noise process. Converted to the Bark scale the results of F1 are plotted along the vertical axis and F2 along the horizontal axis. This plots a representation which closely resembles a traditional articulatory vowel chart.

In the Bark scale vowel height is correlated to F1 which is plotted vertically against Barks F2 which is a correlate of vowel backness. F2 is plotted horizontally in the vowel quadrilateral from right to left. Each point in the graph represents the controid (mean F1-F2 coordinates) in the acoustic vowel space measured at the temporal midpoint of the word tokens produced by the Sinhala/SSLE bilinguals.

RESULTS AND ANALYSIS

Figures 3 and 4 present acoustic vowel quadrilaterals of eleven English vowels produced by a male and a female participant who are Sinhala/SSLE bilinguals. Proof for the statement 'a speaker-independent measure of vowel quality is still elusive' by Deterding [36] is produced by the following analysis.

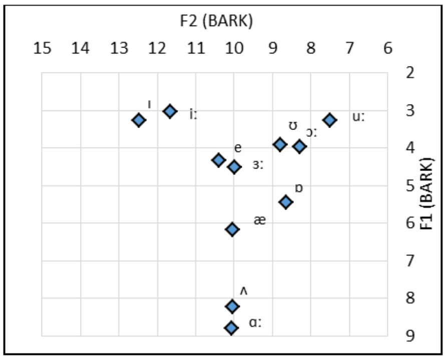

Fig-4: Quadrilateral- Male participant

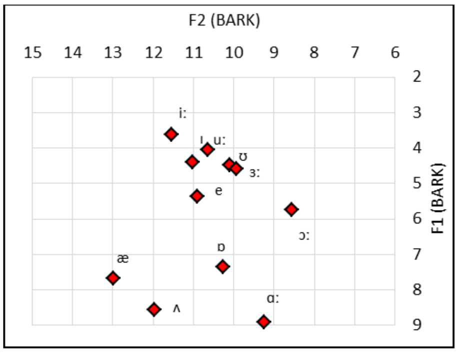

Fig-5: Quadrilateral- Female participant 2

Individual vowel formant values plotted on a quadrilateral along a Bark scale illustrated in the figures above show a noticeable difference in the vowel spaces of male and female participants.

This is agreement with the findings of Deterding [36] for speakers of SSBE. Thus mean averages were calculated for the English vowels produced by Sinhala/SSLE bilinguals and the mean values for SSBE were calculated using data in Deterding [36]. The results are in Table 2 below.

Table-7: Mean average formant values SSLE and SSBE [36]

Variety / Formant / Vowel	SSBE		SSLE	
	F1	F2	F1	F2
i:	431	2451	405	1669
I	375	1965	416	1556
e	606	1856	576	1458
æ	1120	1408	829	1414
ʌ	779	1359	907	1360
ɑ:	778	1235	1038	1286
ɒ	654	1131	726	1191
ɔ:	402	858	611	1054
ʊ	394	1256	459	1197
u:	322	1314	451	1201
ɜ:	542	1565	484	1263

The analysis of the language specific articulation of F1 formants of the vowels in the figure below shows that SSLE users rarely tend to produce a good approximation of their equivalents in SSBE. An upward shift in the F1 dimension of the vowels in SSLE relative to the equivalent vowels in SSBE is indicated in /ɪ, ʌ, ɑ:, ɒ, ɔ:, ʊ, u:/. As a higher F1 value results in the vowel becoming lower, vowel lowering is witnessed in differing degrees in these vowels. As low vowels are more open it could be stated that these SSLE vowels in general are more open than their counterparts in SSBE. A fairly close F1 approximation to SSBE is indicated by / i:, e, ɜ:/. The low vowel / æ/ of SSBE has a significant rising making the SSLE vowel less open. Thus the trend in the F1 data was a direction of change which varied among vowel categories.

Though the SSLE F2 formants did not vary to extent the F1 frequencies did when compared to SSBE they too were not generally in approximation. Special attention is requested to the vowels / i:, ɪ, e, ɜ:/ as the F2 formants are significantly lower than their values in SSBE. This is an indication that in SSLE the high and mid high front vowels is backed. Considering the back vowel /ɒ/ there is a marginal fronting. This makes the language specific, within the category acoustic space clustering of SSLE tighter than in SSBE.

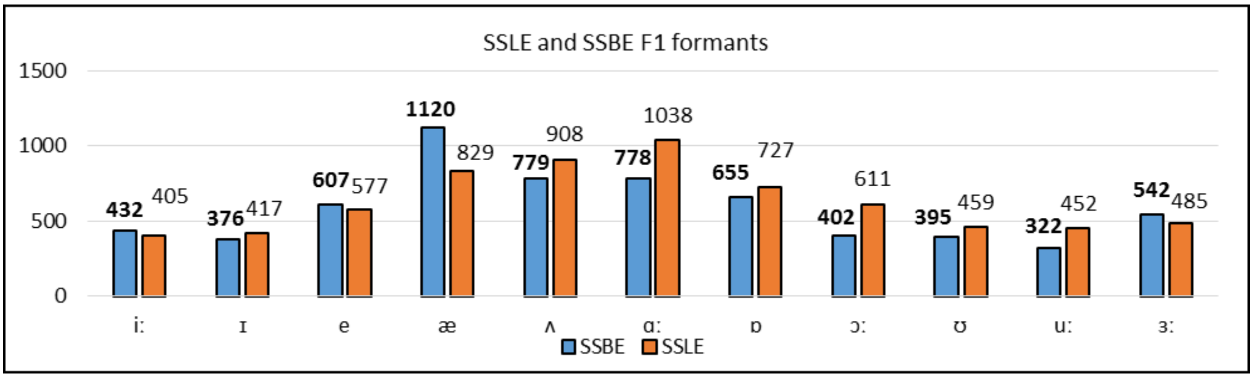

Fig-6: Comparing SSLE and SSBE F1 formants

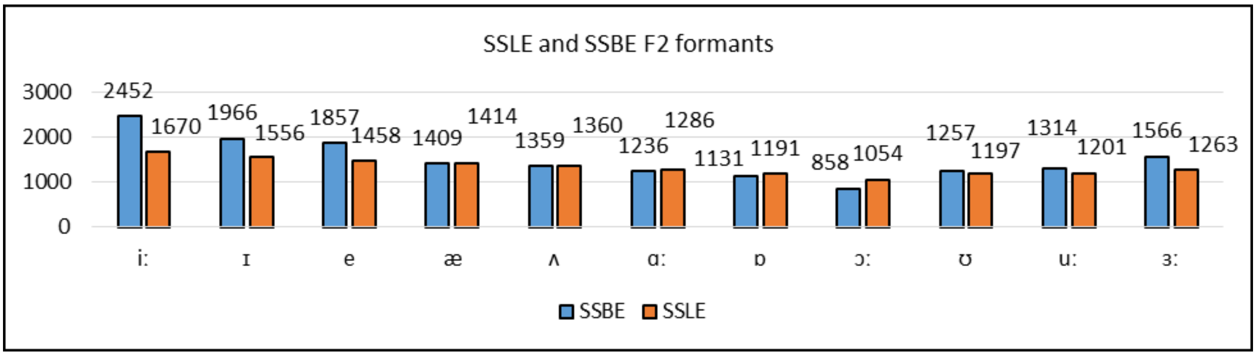

Fig-7: Comparing SSLE and SSBE F2 formants

Though the SSLE F2 formants did not vary to extent the F1 frequencies did when compared to SSBE they too were not generally in approximation. Special attention is requested to the vowels / iː, ɪ, e, ɜː/ as the F2 formants are significantly lower than their values in SSBE. This is an indication that in SSLE the high and mid high front vowels are backed. Considering the back vowel /ɒ/ there is a marginal fronting. This makes the language specific, within the category acoustic space clustering of SSLE tighter than in SSBE.

Acoustic vowel quadrilaterals presented in Figures 7 and 8 illustrate the vowel spacing for SSLE and SSBE. Shaiman [42] states the size and shape of the cavities created by jaw opening is represented by the F1 frequencies and F2 formants roughly relate to tongue position and the Vowel Space Area is an acoustic proxy for the movements of the articulators.

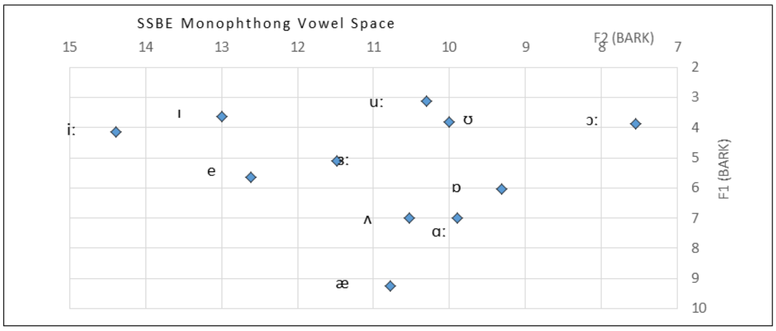

Fig-7: Vowel spacing for SSBE

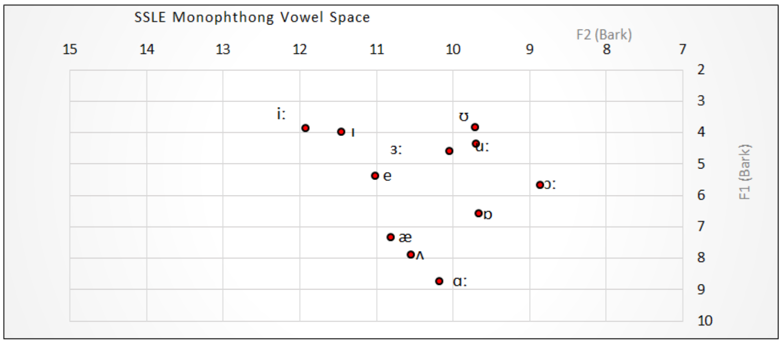

Fig-8: Vowel spacing for SSLE

The above figures compare the locations of the common vowel categories of SSBE and SSLE in the acoustic space to observe whether a language specific configuration exists in the arrangement of the vowels in the acoustic space. Tightness of within the category clustering is examined. SSBE as illustrated in Figure 7 has an English vowel space which is less tightly-clustered than that of the SSLE speakers. Bradlow and Bent [43] state that clearer and more intelligible speech is reflected through a larger VSA while smaller VSAs are associated with less intelligible speech.

Thus this study uses an acoustic difference measurement for vowel intelligibility introduced by Baart [44]. Baart (ibid: 67) states that 'if two sounds are to be perceived as acoustically different, there must be at least 200 Hz difference between the two F1s, and about 400 Hz difference between the two F2s'. This study uses the following measure to gauge the level of intelligibility.

Table-8: Intelligibility and F1 Distance

Measure	Intelligibility
200< F1	Significant difference
100< F1<200	Fairly significant difference
50< F1<100	Marginal difference
0< F1<50	Close approximation

Table-9: Identifying areas of significant difference in F1 Frequency between SSLE and SSBE vowels

Vowel	F1 Frequency (Hz)		Difference (Hz)	SSLE vowel in comparison with the SSBE vowel
	SSBE	SSLE		
iː	431	405	26	Close approximation
ɪ	375	416	41	Close approximation
e	606	576	29	Close approximation
æ	1120	829	291	Significant difference: higher/less open
ʌ	779	907	128	Fairly Significant difference: lower/ more open
ɑː	778	1038	260	Significant difference; lower/ more open
ɒ	654	726	72	Marginal difference
ɔː	402	611	209	Significant difference: lower/ more open
ʊ	394	459	64	Close approximation
uː	322	451	129	Fairly significant difference: lower/ more open
ɜː	542	484	57	Marginal difference

Ladefoged [12] has noted that F1 plays a more salient role in the perception of vowels than F2 because the former has 80% of the total acoustic energy of the vowel. Therefore, F1 can be used reliably to assess vowel intelligibility. The above analysis evidences that the SSLE vowels /æ, ɑː, ɔː/ portray a significant F1 formant difference from SSBE. Many scholars including Flege [16], Munro [45] concur that the English vowels/æ, ɑ, ɔ/ produced by bilinguals with English as their L2 cause intelligibility complications. Based on Baart [44] [] the following measure gauges the influence of F2 on the level of intelligibility.

Table 10: Intelligibility and F2 Distance

Measure	Intelligibility
400< F2	Significant difference
200< F2<400	Fairly significant difference
100< F2<200	Marginal difference
50< F2<100	Close approximation

Table-11: Identified areas of significant difference in F2 Frequency between SSLE and SSBE vowels

Vowel	F2 Frequency (Hz)		Difference (Hz)	SSLE vowel in comparison with the SSBE vowel
	SSBE	SSLE		
iː	2452	1670	782	Significant difference: backed
ɪ	1966	1556	410	Significant difference: backed

The vowels /iː, ɪ/, due to significant F2 formant difference from SSBE, are likely to impinge on intelligibility than other vowels. Combining decreased front vowel F2 with increased back vowel F2 yields a narrowed F2 range, consistent with the overall compressed vowel space.

Thus selecting /æ, ɑː, iː, ɪ, ɔː, oː/ this study examines whether Sinhala, the L1 of the bilinguals has influenced the vowel shifts in SSLE in reference to SSBE. The findings are documented in Table 12 below.

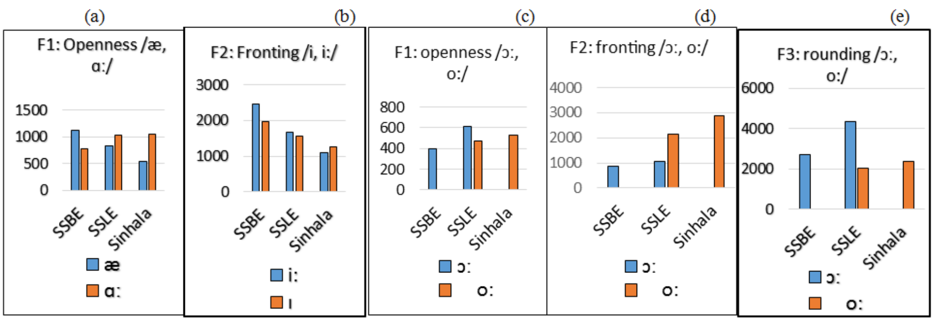

Fig-9: SSLE vowels with significant F1and F2 difference to SSBE and the influence of Sinhala

As illustrated in Figure 9a /æ/ in Sinhala is the least open while in SSBE it is high in openness. Thus influence of Sinhala makes the SSLE user lower the SSBE openness during enunciation. On the other hand /ɑː/ increases its openness as its Sinhala counterpart is a very open vowel.

Figure 9b shows that /iː, ɪ/ are fronted in SSBE and influenced by Sinhala, users of SSLE moves them backwards. /ɔː/ is an alien vowel in Sinhala while /oː/ is alien in SSBE phonology. Users of SSLE have to differentiate between these two vowels as they are diverse phonemes. This differentiating mechanism makes the SSLE /ɔː/ more open, fronted and rounded than its SSBE counterpart.

CONCLUSIONS

The language specific articulation of the SSLE vowels indicates a general downward shift in the F1 dimension of its vowels relative to the equivalent vowels in SSBE. A fronting of the SSLE back vowels and a backward movement of the front SSLE results in a tightness within the SSLE vowel clustering in its vowel space. Acoustic evidence compiled shows that SSLE pronunciation of the vowels /æ, ɑː, iː, ɪ, ɔː, oː/ are strongly influenced by the mother tongue: Sinhala, of the participants.

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