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ABSTRACT

The purpose of this research paper is to describe the acoustic phonetic features of the epenthetic vowel inserted by Spanish-accented speakers of English in sC syllable onsets. Numerous studies have examined this issue. Many have identified the epenthetic vowel as [ɛ]. However, its true acoustic phonetic identity has not been established. This is the first study of its kind that relies on acoustic phonetic measurements to examine the epenthetic vowel. Formant correlates (F0, F1, F2, F3, F4), intensity, and duration cues are used in revealing the true properties of this epenthetic vowel. The insights derived from this study also have technological applications.

Keywords: Acoustic Phonetics, Epenthetic Vowel, Formant Extraction, Minimal Sonority Distance Principle (MSDP), Obligatory Contour Principle (OCP), Spanish-Accented English, Sonority Sequence Principle (SSP), Syllable Phonotactics, Vowel Epenthesis

1.0 Overview

Yun (2016:15) states that vowel epenthesis is a phenomenon that takes place when a consonant cluster of a source language is not allowed in the borrowing language. Hall (2006:1) defines an epenthetic vowel as a phonological segment inserted in order to repair illicit structures. The phenomenon has been broadly studied in many languages such as Cantonese (Tarone, 1980), Vietnamese (Benson, 1988), Amoy (Pennington & Ku, 1993), Farsi (Boudaoud & Cardoso, 2009), Korean (Jong & Park, 2012), Welsh (Olson, 2018; Hannans, 2009), Spanish (Carlisle, 1983 and 1988; Hancin-Bhatt & Bhatt, 1997), Norwegian (Bradley, 2002), Brazilian Portuguese (Bettoni-Techio, Rauber, & Koerich, 2007; Cardoso, 2005; John & Cardoso, 2017), German (Jannedy, 1994), among others.

In past studies, the literature on the topic has shown that many terms have been used in relation to epenthetic vowels. For example, they have also been called *excrescent, parasitic, transitional, weightless,* and *intrusive* vowels. There is no consensus on these terms. For this reason, throughout this paper I will adhere to the most widely accepted terms of "vowel epenthesis" and "epenthetic vowel." The literature also refers to the vowel [ɛ] as the epenthetic vowel introduced by Spanish-accented speakers of English in sC clusters at the beginning of words. However, this claim has not been scientifically proven nor discarded. This paper aims at verifying if the vowel sound [ɛ] is indeed the vowel that is inserted in those sC clusters.

2.0 Methodology

This study aims at answering this question: *"What are the acoustic phonetic properties of the epenthetic vowel inserted in sC onsets in Spanish-accented English?"* Additionally, it will provide relevant data that will help answer other questions, such as why it occurs, at what rate, its implications for intelligibility, and how this information can help develop and/or improve new language processing technologies such as the ones used in virtual assistants and cloud-based voice service technologies.

The data for this study was retrieved from the Speech Accent Archive (SAA) (http://accent.gmu.edu/). The elicitation text contains ten words that are prone to cause epenthesis insertion in Spanish-accented speakers of English. The text from which data is extracted is below. The highlighted words are the ones studied in this paper.

> *Please call **Stella**. Ask her to bring these things with her from the **store**: Six **spoons** of fresh **snow** peas, five thick **slabs** of blue cheese, and maybe a **snack** for her brother Bob. We also need a **small** plastic **snake** and a big toy frog for the kids. She can **scoop** these things into three red bags, and we will go meet her Wednesday at the train **station**.*

2.1 Participants

Data from 10 recordings retrieved from the SAA will be used in the research. Using data from an online public archive guarantees both the replicability of the study and the anonymity of the participants. The participants are five males and five females, all of whom are Spanish native speakers. They all have different ages of onset (AOO), learning methods, and length of residence (LOR). Their relevant sociometric information is displayed in Table 1. They are identified by the number of their recordings in the archive. The letters F and M after the number indicate the gender of the participant.

Participant	Age	AOO	Learning Method	LOR
Spanish 4F	21	17	Academic	4 years
Spanish 8M	21	12	Academic	0.5 years
Spanish 10M	48	47	Academic	10 years
Spanish 28F	20	18	Academic	2 years
Spanish 66M	30	12	Naturalistic	18 years
Spanish 101F	39	19	Naturalistic	24 years
Spanish 104F	28	20	Naturalistic	8 years
Spanish 107M	36	14	Naturalistic	22 years
Spanish 121M	34	21	Academic	10 years
Spanish 137F	24	21	Academic	4 years

Table 1. Participants

2.2 Analysis

Spectrograms such as the one in Figure 1 were created using Praat.

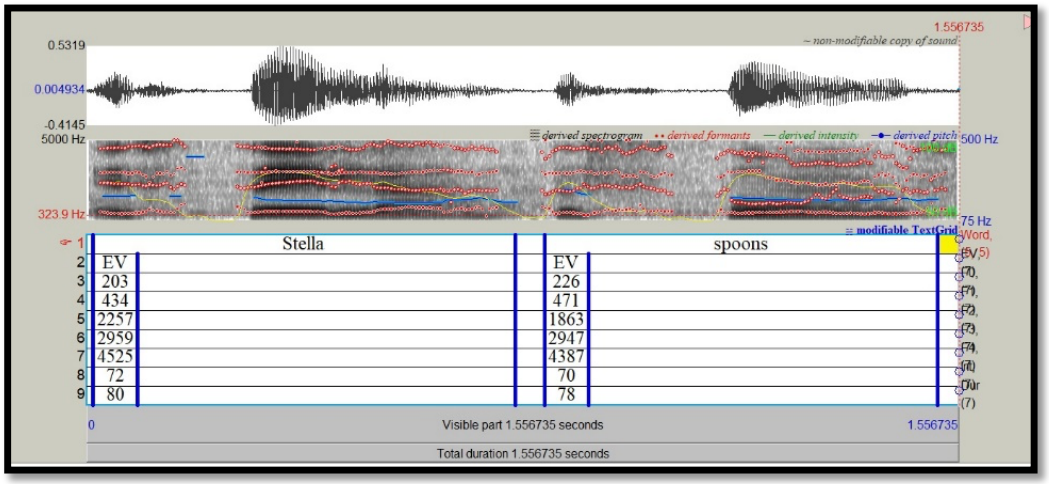

Figure 1. Example of a spectrogram

Pitch/F0, formants (F1, F2, F3, and F4), intensity, and duration information were extracted. Each spectrogram has nine tiers with the values. Formants are measured in Hertz (Hz), intensity is measured in decibels (Db), and duration is measured in milliseconds (msec). All in all, the findings to be discussed in this paper are based on 900 tokens, that is, 10 speakers x 10 words x 9 tiers. The measurements are analyzed and compared to other English vowel sounds produced by Salvadoran-accented English (SAE) speakers and General American English (GAE) speakers. F1 and F2 are used to indicate where and how the epenthetic vowel sound is articulated. This helps determine if the epenthetic vowel produced by SAE speakers differs articulatorily from other vowels that they also produce. Intensity levels are calculated to compute the sonority environments where the epenthetic vowels are inserted and to determine how loud they are when compared to other vowels. Duration is measured to determine if the epenthetic vowel is produced with the same duration as other vowels.

2.3 Rate of Epenthesis

Each recording includes ten words with consonant clusters beginning with sC in onset position (***St****ella, **st****ore, **sp****oons, **sn****ow, **sl****ab, **sn****ack, **sm****all, **sn****ake, **sc****oop,* and ***st****ation*). If, for example, a participant inserts an epenthetic vowel in 6 of the 10 words, their vowel epenthesis insertion rate will be 60%. The same calculation applies to the rate of epenthesis for each word. If 8 participants insert an epenthetic vowel in the word *Stella,* for example, the rate of epenthesis insertion for that word will be 80%.

3.0 Phonological Reasons for Epenthesis Insertion

Epenthesis occurs in Spanish-accented English due to syllable phonotactics. Structurally, English and Spanish syllables look very similar. Both languages allow, for example, simple and complex onsets in word-initial positions. In fact, both languages allow any consonants to occur in syllable onsets. Complex onsets are also possible in English and in Spanish, but the Spanish ones are restricted by several phonotactic rules. Spanish complex onsets can have only two segments, as in the syllable canonical patterns below:

1. V
2. VC
3. CV
4. VCC
5. CVC
6. CCV
7. CVCC
8. CCVC
9. CCVCC

English, conversely, not only allows the structures above, but the following combinations are also possible:

1. CCCV
2. CCCVCC
3. CVCCC
4. CVCCCC

3.1 Phonological Principles Regulating Syllables

Spanish syllable patterns in onset positions are regulated by general phonological principles such as the Minimal Sonority Distance Principle (MSDP), the Sonority Sequence Principle (SSP), and the Obligatory Contour Principle (OCP). English syllables, however, do not necessarily follow those principles. The aforementioned principles are explained succinctly in the following subsections.

3.1.1 Minimal Sonority Distance Principle

In Spanish phonotactics, the Minimal Sonority Distance Principle (MSDP) precludes the segments that are not separated by at least 3 dB from forming a cluster (Koffi, 2020:19). In English, onset clusters that violate the MSDP are permissible. The words *Stella, store, scoop,* and *station* violate the MSDP because only 1 dB separates the segment [s] from [t], or [s] from [k]. The sonority index of [s] is 12, while that of [t] and [k] is 11 dB. The sonority distances between segments are only 1 dB. Since these clusters violate the MSDP, they are disallowed in Spanish, but not in English. This explains why Spanish speakers of English insert an epenthetic vowel before the segment [s] in such syllable onsets.

3.1.2 Sonority Sequence Principle

The Sonority Sequence Principle (SSP) mandates that onsets must rise in sonority towards the nucleus and codas must fall in sonority from the nucleus. The words *Stella, store, scoop,* and *station* also violate this phonotactic rule. This can be clearly exemplified by contrasting the sonority profile of the English word *star* to the Spanish word *estar* (to be). Sonority does not rise between [s] and [t] in the word *star.* Therefore, it violates the SSP. As noted previously, the cluster composed of [s] and [t] also violate the MSDP. The Spanish word *estar* does not violate any of the phonotactic constraints because it is divided into two syllables, *es-* and *-tar.*

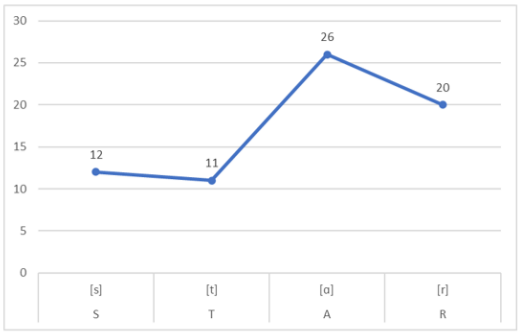

Figure 2. Sonority Profile of the word *"star"*

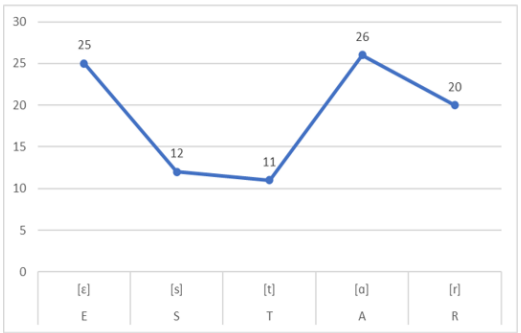

Figure 3. Sonority Profile of the word *"estar"*

3.1.3 Obligatory Contour Principle

The Obligatory Contour Principle (OCP) precludes syllables from containing continuous segments produced in the same place of articulation. The onset clusters [sn] and [sl] violate this principle because both segments in the clusters are articulated in the alveolar ridge. This explains why Spanish does not allow these sound sequences to occur in syllable onsets.

3.2 Summary of Constraints

Because of the MSDP, SSP, and OCP, the only clusters that are permissible in syllable onsets in Spanish are:

1. /k, b, f, g, k, p, t/ + /r/
2. /k, b, f, g, k, p, t/ + /l/[1]
3. /d, t/ + /r/

The phonotactic constraints outlined in the previous sections play an important role in vowel epenthesis insertion for SAE speakers. Since Spanish strictly adheres to these principles, speakers are prone to resolve phonological difficulties by deleting sounds, substituting them, or in the case of sC English onsets, inserting an epenthetic vowel to break up illicit syllable clusters at the beginning of words.

4.0 Results

In light of the phonotactic constraints discussed previously, the rate of epenthesis in the data was calculated. Seven out of the ten participants inserted an epenthetic vowel in at least four out of the ten words under study. Two participants, Spanish 101F and Spanish 104F, inserted an epenthetic vowel in all the ten words. In total, an epenthesis vowel insertion occurred in 53 out of 100 words. The SAE participants in this study made use of an epenthetic vowel in one out of every two times that an sC English onset cluster occurred in the text. The frequency of epenthesis by word is as follows:

1. spoons (70%)
2. Stella (60%)
3. Snake (60%)
4. Scoops (60%)
5. station (60%)
6. store (50%)
7. snow (50%)
8. slabs (50%)
9. snack (40%)
10. small (30%)

Table 2 displays the rate of epenthesis by word and by participant.

	Stella	store	spoons	snow	slabs	snack	small	snake	scoop	station	Total
Spanish 4F	YES	NO	YES	NO	YES	NO	NO	YES	YES	YES	6
Spanish 8M	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
Spanish 10M	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES	8
Spanish 28F	NO	NO	YES	YES	YES	NO	NO	YES	NO	NO	4
Spanish 66M	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
Spanish 101F	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	10
Spanish 104F	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	10
Spanish 107M	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
Spanish 121M	YES	YES	YES	YES	NO	YES	NO	YES	YES	YES	8
Spanish 134F	YES	YES	YES	NO	NO	YES	YES	NO	YES	YES	7
Total	6	5	7	5	5	4	3	6	6	6	53

Table 2. Epenthesis rate by participant and by word

[1] The author is Salvadoran. In Salvadoran Spanish, the combination /t/+/l/ is found only in loanwords from Nahuatl.

The word *small* has the fewest number of epenthesis insertions. It also is worth noting that it is the only word that does not violate any of the phonotactic constraints, (MSDP, SSP, or OCP). In other words, onset clusters that violate these constraints are the most likely to be resyllabified by SAE speakers.

4.1 Acoustic Phonetic Analyses

The previous sections have explained the rate at which and the reasons why SAE speakers in our study insert an epenthetic vowel before sC English onset clusters. Now, it is necessary to turn to acoustic phonetics to understand the identity of the vowel that is inserted. Many phonological and impressionistic auditory accounts claim that the vowel that is inserted is [ɛ]. The analyses in the upcoming sections will situate us on the true phonetic identity of this vowel. For this, we turn to F0, F1, F2, F3, F4, intensity, and duration measurements extracted from the vowel that is inserted at the beginning of these clusters.

4.2 Articulatory Bases of F1 and F2

The F1 formant represents how wide the speaker opens his/her mouth when producing a sound. Vowels can be articulated with different levels of mouth aperture. Depending on how open the mouth is when producing a vowel segment, vowels can be classified as high, mid, and low. When vowels are measured using Praat, the lower the frequency, the higher the vowel. According to Ladefoged (2015:188), the F1 represents the most important correlate to differentiate vowels as it contains 80% of the energy in the vowels. F2 depicts the horizontal movement of the speaker's tongue. Vowels can be articulated with the tongue in front, middle, and back position. Higher measurements in the F2, for example, are associated with front vowels. Even though F2 is not as important as F1 in differentiating vowels, it serves as an indicator for accentedness.

4.2.1 Female Participants

This section addresses the results of the female participants. They produced 37 out of the 50 words with an epenthetic vowel. Since this section deals with F1 and F2 simultaneously, the total number of tokens is 64.

Word		Stella	store	spoons	snow	slabs	snack	small	snake	Scoop	station	Mean
		EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	
4F	F1	527	NA	471	NA	497	NA	NA	485	NA	478	482Hz
	F2	2257	NA	1863	NA	2007	NA	NA	1992	NA	2240	2111Hz
28F	F1	NA	NA	418	449	496	NA	NA	575	NA	NA	484Hz
	F2	NA	NA	1848	1869	1876	NA	NA	2081	NA	NA	1918Hz
101F	F1	669	519	623	446	473	472	451	488	653	587	538Hz
	F2	1975	2105	1923	2102	1886	2366	2451	2223	1980	2280	2129Hz
104F	F1	534	709	472	472	402	538	463	609	601	646	544Hz
	F2	1867	1935	2044	2044	1324	1901	2149	2066	1869	1878	1907Hz
134F	F1	505	487	501	NA	NA	611	713	NA	679	534	575Hz
	F2	2039	1899	2411	NA	NA	1928	1772	NA	1980	2011	2006Hz

Table 3. F1 and F2 results for female particpants

Table 4 summarizes the means for each female participant as well as the group's mean.

	Speaker 4F	Speaker 28F	Speaker 101F	Speaker 104F	Speaker 134F	Group's Mean
F1	482	484	538	544	575	524Hz
F2	2111	1918	2129	1907	2006	2014Hz

Table 4. F1 and F2 means for each female participant and group's mean

The F1 mean of the epenthetic vowel introduced by the 5 female speakers is 524Hz. It corresponds to the face vowel [e], when compared with the data provided by Pena (2019) in his study of the acoustic vowel space of SAE speakers. Pena's mean for the face vowel [e] was 485Hz. Only a difference of 39Hz separates them. Furthermore, according to Hillendbrand (1995), the F1 value in General American English (GAE) for the face vowel [e] produced by female speakers is 536Hz. This means that GAE hearers are likely to perceive the epenthetic vowel as [e] because only 12 Hz separates SAE speakers' epenthetic vowel from GAE speakers' [e] vowel. Thus, the epenthetic vowel introduced by female SAE speakers is a mid-vowel in regard to mouth aperture, and it corresponds to the vowel [e] both in SAE and GAE.

Regarding the F2 mean, the F2 mean value for the epenthetic vowel introduced by female SAE speakers (2014Hz) resembles the trap vowel [æ] value (2050Hz, threshold difference of 36Hz), as reported by Peterson and Barney (1952). The F2 values of the epenthetic vowel introduced by female SAE speakers indicate that it is produced with the tongue in a frontal position in the horizontal axis.

Figures 4 and 5 depict the articulation point of the epenthetic vowel inserted by female SAE speakers in comparison to other vowels articulated by SAE and GAE speakers respectively.

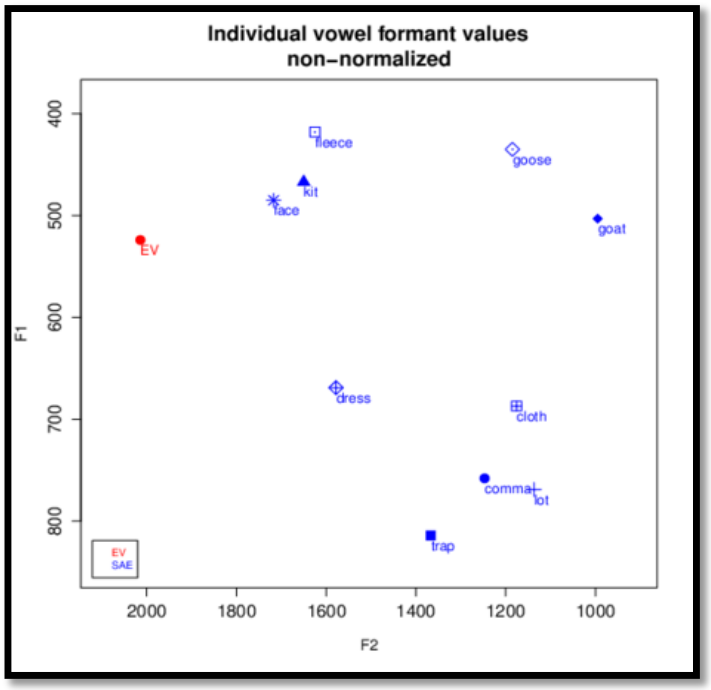

Figure 4. Acoustic Vowel Space of the epenthetic vowel introduced by SAE female speakers compared to SAE females' phonemic vowels

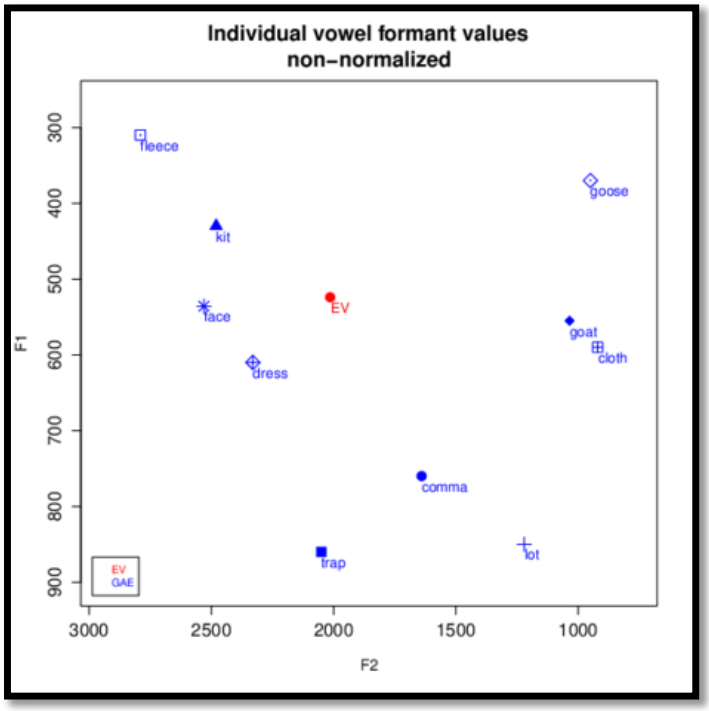

Figure 5. Acoustic Vowel Space of the epenthetic vowel introduced by SAE female speakers compared to GAE females' phonemic vowels

4.2.2 Male Participants

This section is concerned with the results of the male participants. They produced 16 out of the 50 words with an epenthetic vowel. The total number of tokens discussed in this section is 32, 16 for the F1 and 16 for the F2. Speakers 8M, 66M and 107M did not inserted any epenthetic vowels in any of the ten words being studied.

Word		Stella	Store	spoons	Snow	slabs	snack	small	Snake	scoop	station	Mean
		EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	
10M	F1	499	757	320	548	310	NA	NA	462	401	518	477Hz
	F2	1739	2107	1809	1741	2003	NA	NA	1777	1905	2095	1897Hz
121M	F1	442	468	405	381	NA	448	NA	518	408	486	445Hz
	F2	1482	1472	1476	2090	NA	1611	NA	1701	1785	1778	1674Hz

Table 5. F1 and F2 results for male participants

	Speaker 10M	Speaker 121M	Group's Mean
F1	477	445	461Hz
F2	1897	1674	1786Hz

Table 6. F1 and F2 means for each male participant and group's mean

The mean of the F1 measurements of the epenthetic vowel introduced by the two male SAE speakers is 461Hz. This measurement corresponds to the face vowel [e] in Salvadoran-accented English with a value of 455Hz as reported by Pena (2019), threshold difference of only 6Hz, as well as in General American English with a value of 476Hz as reported by Hillenbrand (1995), with a difference of only 15Hz. The primary difference with the females' results is that the males' F2 mean reveal that males' epenthetic vowel

is not as fronted as the females' ones. The epenthetic vowel introduced by male SAE speakers is a mid-vowel regarding the tongue's horizontal axis (F2), that is, the tongue lays in a neutral position in the middle of the oral cavity.

Figures 6 and 7 depict the articulation point of the epenthetic vowel inserted by male SAE speakers in comparison to other vowels articulated by SAE and GAE speakers respectively.

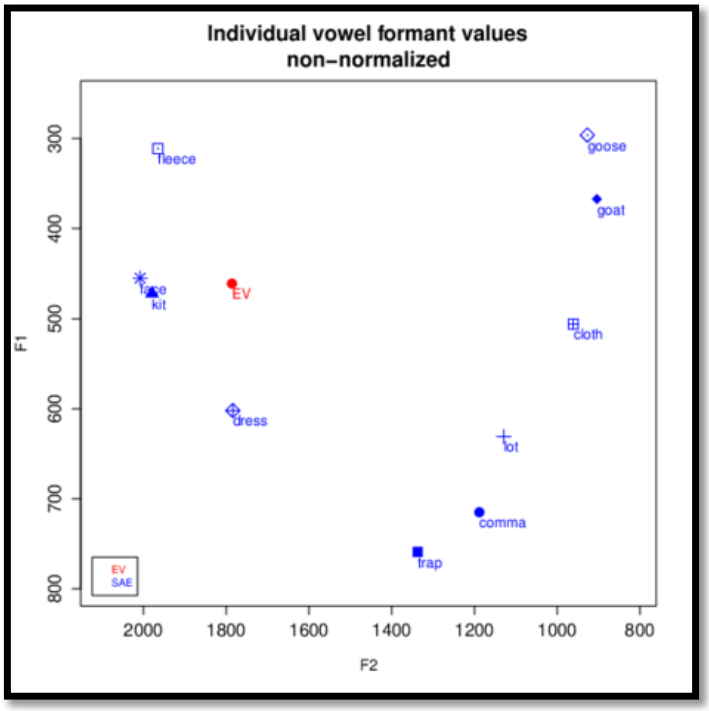

Figure 6. Acoustic Vowel Space of the epenthetic vowel introduced by SAE male speakers compared to SAE males' phonemic vowels

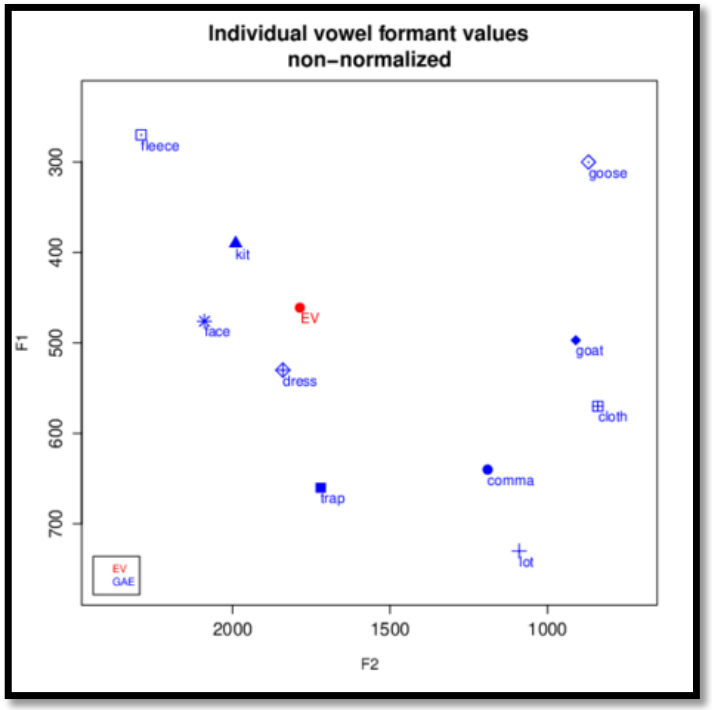

Figure 7. Acoustic Vowel Space of the epenthetic vowel introduced by SAE male speakers compared to GAE males' phonemic vowels

4.3 Patterns and Tendencies for All Participants

The first pattern that should be highlighted is the one followed by speakers 8M, 66M and 107M. They did not introduce any epenthetic vowels in any of the ten words being studied. This could be attributed to their early age of onset. They reported starting learning English at a very early age. Though the learning method varied, the findings lend credibility to the Critical Period Hypothesis, at least for the acquisition of the sC English clusters in onset position. The remaining seven participants started learning English when they were 17 years old, or older. This may explain why they insert an epenthetic vowel into sC syllable clusters.

The F1 value distribution is displayed in Table 7 and Figure 8. The difference between the highest value obtained (757Hz) and the lowest (310Hz) was 447Hz. By the F1 measurements, we see that the epenthetic vowel is not the same for all speakers. For some speakers, it has the characteristics of a high vowel, for others, it is a middle vowel. For a third group of speakers, it is a low vowel. However, as Figure 1 indicates, in most of the occurrences (28 out of 53), it corresponds to a middle vowel.

F1 Values	Frequency
310-354	2
355-399	1
400-444	7
445-489	17
490-534	11
535-579	3
580-624	5
625-669	3
670-714	3
715-760	1
Total	53

Table 7. F1 Frequencies

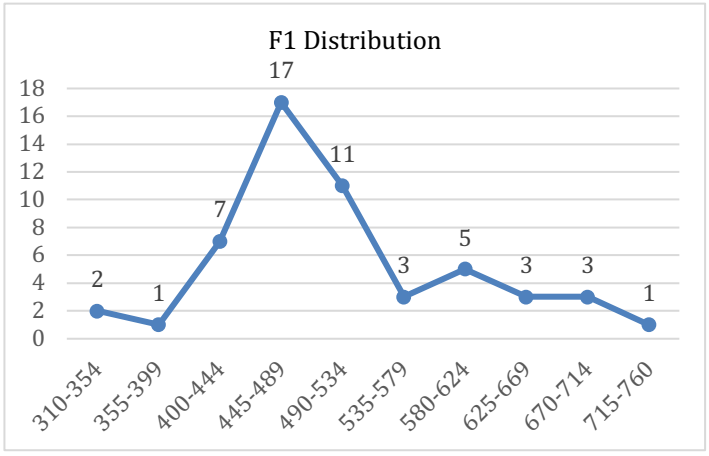

Figure 8. Distribution of F1 values for SAE speakers

The F2 value distribution is displayed in Table 8 and Figure 9. Some speakers produced the epenthetic vowel almost as a back vowel. This can be noted when its F2 value is less than 1400 Hz. However, most of the time, it is produced either as a mid vowel or a front vowel. When F2 measurements are taken together with those of F1, it can be concluded the epenthetic vowel is most of the time the vowel [e], as noted in previous sections. Again, the acoustic vowels spaces in Sections 4.2.1 and 4.2.2 support this conclusion.

F2 Values	Frequency
1310-1424	1
1425-1539	3
1540-1654	1
1650-1769	3
1770-1884	12
1885-1999	11
2000-2114	13
2115-2229	2
2230-2344	4
2345-2459	3
Total	53

Table 8. F2 Frequencies

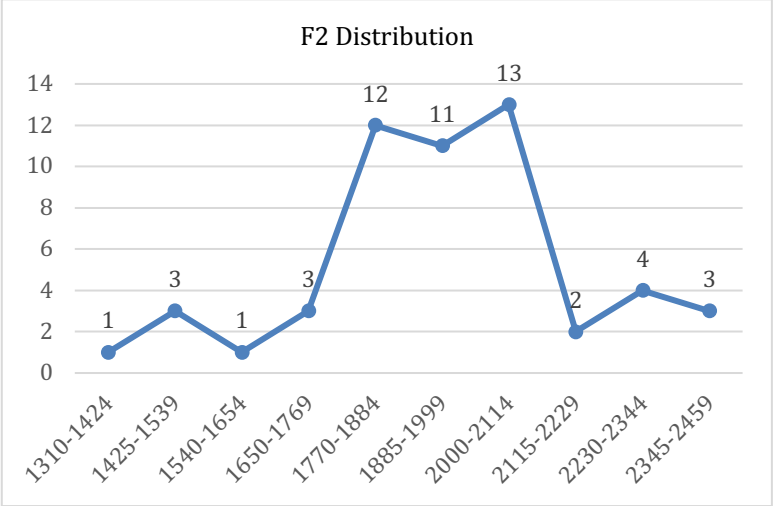

Figure 9. Distribution of F2 values for SAE speakers

4.4 Other Acoustic Characteristics of the Epenthetic Vowel

In addition to F1 and F2, the study also examined the F0, intensity, duration, and F3 and F4 properties of the epenthetic vowel.

4.4.1 F0 Measurements

The mean F0 of the epenthetic vowel produced by female SAE speakers is 232Hz. The result is obtained from calculating the mean of 33 epenthetic vowels produced by female SAE speakers in sC onset-initial words. Although 37 epenthetic vowels were identified, four of them presented an “undefined” F0/pitch.

	Stella	Store	Spoons	Snow	Slabs	Snack	small	snake	Scoop	station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
4F	203	NA[2]	226	NA	233	NA	NA	NA	201	185
28F	NA	NA	292	211	234	NA	NA	214	NA	NA
101F	259	163	289	222	261	236	211	165	262	203
104F	243	310	NA	123	104	205	219	225	218	224
134F	237	214	254	NA	NA	211	214	NA	NA	NA

Table 9. F0 measurements (in Hz) for female SAE speakers

Males also produced the epenthetic vowel with a mean F0 of 126 Hz. The result is based on the mean of 11 epenthetic vowels. Males produced 16 epenthesis insertions; however, Praat indicated that five had an undefined F0/pitch. Those five words were all produced by Spanish 10M. Spanish 121M did not insert an epenthetic vowel in the word *small*.

	Stella	Store	Spoons	Snow	Slabs	Snack	small	Snake	scoop	Station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
10M	NA[3]	NA	NA	NA	122	NA	NA	111	NA	120
121M	107	108	137	135	NA	111	NA	162	133	142

Table 10. F0 measurements (in Hz) for male SAE speakers

4.4.2 Intensity Measurements

The mean intensity of epenthetic vowels produced by female SAE speakers is 68 dB, as shown in Table 11.

	Stella	store	spoons	snow	slabs	snack	small	snake	scoop	station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
4F	72	NA	70	NA	65	NA	NA	64	70	68
28F	NA	NA	68	65	68	NA	NA	62	NA	NA
101F	72	65	72	70	70	75	76	69	71	68
104F	67	58	59	71	68	67	72	63	72	72
134F	73	63	78	NA	NA	71	73	NA	60	58

Table 11. Intensity measurements (in dB) for female SAE speakers

The intensity of the epenthetic produced by males is 67dB. The individual values for each word are displayed in Table 12.

	Stella	Store	Spoons	Snow	Slabs	Snack	Small	Snake	scoop	Station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
10M	63	63	68	65	74	NA	NA	67	69	67
121M	66	72	68	55	NA	67	NA	68	65	75

Table 12. Intensity measurements (in dB) for male SAE speakers

The fact the intensity measurements by females and males are 68 dB and 67 dB, respectively, speaks to the fact that the epenthetic vowel is sufficiently loud. If it were a schwa, it would not be as loud. The epenthetic vowel is as loud as the vowels [u] (67.7 dB) and [ʊ] (67.7 dB) in male speech as reported by Pena (2019:43). Furthermore, the

[2] An epenthetic vowel was not inserted in these words, or it was inserted but the F0/pitch value was either undefined because it was under 75Hz.
[3] An epenthetic vowel was not inserted in these words, or it was inserted but the F0/pitch value was either undefined because it was under 75Hz.

intensity of 68 dB in female speech shows that it is louder than all the vowels produced by the female participants in Pena (2019:43). Again, all this underscores the fact the epenthetic vowel is a full-blown vowel.

4.4.3 Duration

Praat measures duration in seconds, though for the current analysis the results are reported in milliseconds (*msec*). Though this correlate does not play a significant role in distinguishing vowels, it provides us with valuable information about the length of a vowel in a speech.

The mean duration of the epenthetic vowels produced by female SAE speakers is 84.5 msec. The values are displayed in Table 13.

	Stella	store	spoons	snow	slabs	snack	small	snake	Scoop	station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
4F	80	NA	78	NA	74	NA	NA	67	88	76
28F	NA	NA	80	88	75	NA	NA	80	NA	NA
101F	95	77	82	79	104	102	131	128	88	104
104F	122	71	50	79	59	81	97	58	100	98
134F	63	74	68	NA	NA	74	90	NA	85	80

Table 13. Duration measurements (in msec) for female SAE speakers

The mean duration of the epenthetic vowels produced by male SAE speakers is 100 msec. The values are presented below in Table 14.

	Stella	store	spoons	snow	Slabs	snack	small	snake	Scoop	station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
10M	106	100	78	86	87	NA	NA	126	93	155
121M	85	168	69	58	NA	110	NA	96	62	123

Table 14. Duration measurements (in msec) for male SAE speakers

When compared with the vowels produced by the participants in Pena's study (2019:40), we see that the epenthetic vowel is much shorter. The average duration of vowels in Pena produced by females is 233 msecs. By producing the epenthetic vowel with only 84.5 msec, they shorten the epenthetic vowel's duration by 148.5 msec when compared to the average of SAE vowels. We see that it is 148.5 msec shorter. The same observation can be made for males. Pena (2019) reports that the average duration of vowels is 220 msec. However, the epenthetic vowel produced by male speakers is only 100 msec. They also shorten it by 120 msec. Therefore, the epenthetic vowel inserted by both groups has a duration long enough to be considered a full vowel, yet it is distinguishable from other SAE vowels by its brevity.

The short duration of the epenthetic vowel is one of the reasons why Hall (2006) calls it *vowel intrusion* or *intrusive vowel*, which she defines as a phonetic transition between sounds. However, the epenthetic vowel inserted by SAE speakers continues having the F1 and F2 values of a phonemic vowel, as well as the intensity and pitch correlates. This has been demonstrated in the previous sections.

4.4.4 F3 Formant

The F3 bandwidth values are correlated with lip roundedness. The lower the formant frequency, the rounder shape of the lips. Though these correlates do not influence intelligibility as their F1 and F2 counterparts, they provide valuable information about certain particularities that take place in the production of sounds in a variety of English.

F3 for Female Participants

The mean F3 of the epenthetic vowel produced by female SAE speakers is 2941Hz. This result casts light on the fact that the epenthetic vowel produced by female SAE speakers is an unrounded vowel. This measurement is based on a mean of 37 epenthetic vowels introduced by female SAE speakers in sC onset-initially words. The participants' individual productions are summarized in Table 15 below.

	Stella	Store	spoons	Snow	Slabs	Snack	small	snake	Scoop	Station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
4F	2959	NA	2947	NA	2869	NA	NA	2863	2890	2955
28F	NA	NA	2983	2998	3032	NA	NA	3149	NA	NA
101F	3043	2987	3030	3003	2831	3088	3065	2988	2970	3140
104F	2607	3150	2763	2778	2876	2657	2951	2893	2689	2955
134F	2883	2943	2803	NA	NA	2919	2960	NA	3126	3074

Table 15. F3 measurements (in Hz) for female SAE speakers

F3 for Male Participants

The mean F3 of the epenthetic vowel introduced by male SAE speakers is 2742Hz. The result was obtained from calculating the mean of the 16 epenthetic vowels produced by male SAE speakers in sC onset-initial words. The individuals' production is displayed in Table 16.

	Stella	Store	Spoons	Snow	Slabs	snack	small	Snake	scoop	Station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
10M	2628	2891	2700	2801	2571	NA	NA	2788	2743	2774
121M	2667	2410	2579	3687	NA	2515	NA	2492	2897	2742

Table 16. F3 measurements (in Hz) for male SAE speakers

4.4.5 F4 Formant

Dusosky (2022:84) explains that "the physiological correlate of F4 is unclear but it has been posited that it may correlate with the length of the vocal tract (or laryngeal cavities) or the size of the speaker's head." For the present analysis, Ladefoged's perspective will be followed, that is, the F4 results will be analyzed as an inverse relationship between the F4 measurement and the size of the speaker's head. Smaller F4 values will be interpreted as speakers with bigger heads, while bigger F4 measurements will be interpreted as produced by speakers with smaller heads. As noted in the previous section, these correlates do not influence intelligibility in any way, but they provide valuable information about certain particularities that take place in the production of sounds in a variety of English.

F4 for Female Participants

The mean F4 of the epenthetic vowel produced by female SAE speakers is 4118Hz based on 37 epenthetic vowel tokens. Table 17 presents the data gathered after extracting the F4.

	Stella	Store	Spoons	Snow	Slabs	Snack	small	Snake	Scoop	Station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
4F	4525	NA	4387	NA	4493	NA	NA	4445	4482	4545
28F	NA	NA	4505	4312	4557	NA	NA	4571	NA	NA
101F	3837	3987	3953	3790	3885	4020	3792	4051	3979	4067
104F	3475	4086	3804	3957	3685	3529	3710	4101	3650	3923
134F	4416	4276	4212	NA	NA	4287	4192	NA	4423	4457

Table 17. F4 measurements (in Hz) for female SAE speakers

F4 for Male Participants

The mean F4 of the epenthetic vowel produced by male SAE speakers is 3861Hz from 16 epenthetic vowel tokens displayed in Table 18.

	Stella	Store	Spoons	snow	Slabs	snack	Small	Snake	scoop	Station
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
10M	3533	3867	3811	3854	3946	NA	NA	3783	3777	3892
121M	3831	3386	4092	4574	NA	3675	NA	4028	4056	3677

Table 18. F4 measurements (in Hz) for male SAE speakers

5.0 Technological Applications

The measurements presented in this study provide a holistic analysis of the acoustic phonetic properties of the epenthetic vowel produced by SAE speakers. They can be used to train speech-enabled intelligent systems devices, cloud-based voice services, and in language teaching computer programs to improve the intelligibility of SAE speakers. This process can be done by calculating the mean values of the epenthetic vowel and having computers interpret the data as another independent sound in initial position in sC onset-initial words.

6.0 Summary

Previous studies that have shown that SAE speakers introduce an epenthetic vowel to break up syllable-initial sC clusters. These studies have appealed to phonological and phonotactic constraints to explain why an epenthetic vowel is needed in the first place. To the best of my knowledge, this is the first study to examine the acoustic phonetic properties of the epenthetic vowel. Its averaged F1 and F2 measurements indicate that, in most of the occurrences, it a mid-front vowel, most likely [e] when compared to SAE and GAE. For some speakers and in some clusters, the values indicate that it can also be the vowel [ɛ]. Intensity measurements show that it is a full-blown vowel because it is loud, 68 dB in females' pronunciation, and 67 dB in males'. Its durational measurements paint a picture of a short vowel, only 84.5 msec in females' speech and 100 msec in males'. Its average duration is 120 msec or so less than the average duration of vowels produced by SAE speakers. In other words, the epenthetic vowel that is inserted in sC clusters can be described phonetically as a ***short, mid, audibly perceptible front*** *vowel.*

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References

Benson, B. (1988). *Universal Preference for the Open Syllables as an Independent Process in Interlanguage Phonology.* Language Learning, 38, pp. 221-235.

Bettoni-Techio, M., Rauber. A., & Koerich, R. (2007). *Perception and Production of Word-final Alveolar Stops by Brazilian Portuguese Learners of English.* Proceedings of Interspeech, pp. 2293-2296.

Boudaoud, M. & Cardoso, W. (2009). *Vocalic (e) Epenthesis and Variation in Farsi-English Interlanguage Speech.* Concordia Working Papers in Applied Linguistics, 2, pp. 1-34.

Bradley, T. (2002). *Gestural Timing and Derived Environment Effects in Norwegian Clusters.* WCCFL 21 Proceedings. Cascadilla Press, pp. 101-114.

Cardoso, W. (2005). *The Variable Acquisition of English Word-final Stops by Brazilian Portuguese Speakers.* Proceedings of the 7th Generative Approaches to Second Language Acquisition Conference. Cascadilla Proceedings Project, pp. 38-49.

Carlisle, R. (1983). *Vowel Epenthesis in Spanish/English Interlanguage Phonology.* Papers from the First Conference on the Uses of Phonology, pp 18-45.

Carlisle, R. (1988). *The Effect of Markedness on Epenthesis in Spanish/English Interlanguage Phonology.* IDEAL, pp. 15-23.

de Jong, K. and Park, H. (2012). *Vowel Epenthesis and Segment Identity in Korean Learners of English.* Studies in Second Language Acquisition, 34, pp. 127-155.

Dusosky, S. (2022). *Speech Digitalization, Coding, and Nasal(ized) Vowel Synthesis: Demonstration with Beti, a Critically Endangered Language.* Linguistic Portfolios, 11(6), pp. 82-91. Available at: https://repository.stcloudstate.edu/stcloud_ling/vol11/iss1/6.

French, N. and Steinberg, J. (1947). *Factors Governing the Intelligibility of Speech Sounds.* Journal of the Acoustical Society of America, 19, pp. 90-119.

Hillenbrand, J. (1995). *Acoustic Characteristics of American English Vowels.* The Journal of the Acoustical Society of America, 95, pp. 3099-3111.

Hall, N. (2006). *Cross-linguistic Patterns of Vowel Intrusion.* Phonology, 23, pp. 387-429.

Hall. N. (2011) *Vowel Epenthesis.* The Blackwell Companion to Phonology, 5. Wiley-Blackwell. pp. 1576-1596.

Hannahs, S. (2009). *Welsh Svarabhakti: Sonority Sequencing and Foot Structure.* Journal of Celtic Linguistics, 13, pp. 21-44.

Hancin-Bhatt, B., & Bhatt, R. (1997). *Optimal L2 Syllables: Interactions of Transfer and Developmental Effects.* Studies in Second Language Acquisition 19, pp. 331-378.

Jannedy, S. (1994). *Rate Effects on German Unstressed Syllables.* OSU Working Papers in Linguistics, pp. 105–124.

John, P. & Cardoso, W. (2017). *On syllable structure and phonological variation: The case of i-epenthesis by Brazilian Portuguese learners of English.* SciELO: Scientific Electronic Library Online. Available at: https://www.scielo.br/j/ides/a/84qPK4M6Cx7fjJvwFsyBsNm/.

Koffi, E. (2020). *A Comprehensive Review of Intensity and Its Linguistic Applications.* Linguistic Portfolios 9(2), pp. 2-27. Available at: https://repository.stcloudstate.edu/stcloud_ling/vol9/iss1/2/.

Koffi, E. (2020). *Relevant Acoustic Phonetics of L2 English: Focus on Intelligibility.* CRC Press: Boca Raton, FL.

Ladefoged, P. & Johnson, K. (2015). *A Course in Phonetics*. Seventh Edition. Malden, MA. Cengage Learning.

Olson, D. (2018). *Vowel Epenthesis in Welsh/English Bilingual Children.* The University of Arizona, UA Campus Repository.

Pater, J., & Barlow, J. (2003). *Constraint Conflict in Cluster Reduction.* Journal of Child Language, 30, pp. 487-526.

Pena, J. (2019). *Salvadorian-Accented English Vowels Produced by Teachers of English as a Foreign Language.* Culminating Projects in TESL. St. Cloud State University. Available at: https://repository.stcloudstate.edu/tesl_etds/11.

Pennington, M., & Ku, P. (1993). *Realizations of English Final Stops by Chinese Speakers in Taiwan.* RELC Journal, 24, pp. 29-48.

Peterson, G., & Barney, H. (1952). *Control Methods Used in a Study of the Vowels.* The Journal of the Acoustical Society of America, 24, pp. 175-184. Available at: https://doi:10.1121/1.1906875.

Tarone, E. (1980). *Some Influences on the Syllable Structure of Interlanguage Phonology.* International Review of Applied Linguistics, 18, pp. 139-152.

Yun, S. (2016). *Consonant Cluster Perception and Vowel Epenthesis.* Massachusetts Institute of Technology.