Acoustic and Perceptual Characterization of the Epenthetic Vowel between the Clusters Formed by Consonant + Liquid in Spanish

Carlos Julio Ramírez
University of Toronto

1. Introduction

Previous studies of Spanish phonetics have noted that consonant clusters formed by stop + alveolar liquid flap contain an epenthetic (svarabatic) vowel between the two elements of the cluster (Malmberg 1965, Quilis 1981). This observation stems from dialectological data that show the presence of an epenthetic vowel across different Spanish dialects, as in (1):

(1)

tiguere	[tíγeɾe]	instead of	tigre	[tíγɾe]	"tiger"
chacara	[ʧákaɾa]	instead of	chacra	[ʧákɾa]	"small farm"
gurupa	[guɾúpa]	instead of	grupa	[gɾúpa]	"croup (of horse)"
tarabilla	[taɾaβíʝa]	instead of	trabilla	[tɾaβíʝa]	"small clasp"
coronica	[koɾónika]	instead of	cronica	[kɾónika]	"chronic"

Malmberg also presents some examples showing the presence of a vocalic element in clusters formed by stop + lateral alveolar (henceforth referred to as "lateral"), as in (2), although he does not include these examples in his discussion, and Quilis does not mention them at all.

(2)

Ingalaterra	[iŋgalatera]	instead of	Inglaterra	[iŋglatera]	"England"
indulugencia	[induluxensia]	instead of	indulgencia	[indulxensia]	"indulgence"

Navarro (1963) claims that the epenthetic vowel develops in cases where the single alveolar liquid flap (henceforth referred to as "flap") precedes or succeeds a consonant, and the pitch of the vowel is similar to the syllable to which the flap belongs. Furthermore, he argues that the pronunciation of this vocalic element is unconscious and its duration is comparatively shorter than the full vowel, but in some cases it may develop as a full vowel, as indicated in example (1) above. The presence of the vowel leads Navarro to state that the pronunciation of the Spanish flap is always intervocalic. Navarro does not analyze the occurrence of the epenthetic element in clusters formed with the lateral.

On the other hand, Massone (1988) in her analysis of the speech of two male speakers states that the frequencies of the epenthetic vowel and those of the full vowel are different. She suggests that the frequencies of the formants of the epenthetic are in fact similar to those of [ɾ]. Therefore, she considers the flap in consonant clusters as a vibrant sound that presents a single vibration and is formed by a vocalic element plus an occlusion. However, such an explanation cannot account for the presence of a vocalic element in clusters formed by stop + lateral, such as those shown in (2).

In addition, Guirao and García (1991), in their analysis of syllables formed by consonant + vowel (CV), vowel + consonant (VC), and consonant + consonant + vowel (CCV) pronounced by three male speakers, propose that /l/ and /r/ lack phonetic identity. In other words, they depend on the bordering vowels even though they have different spectrographic behavior (wave shape) and perceptual responses. Thus, /l/ results as a prolongation of the nucleic vowel and /r/ results from an interruption or

 Selected Proceedings of the 2nd Conference on Laboratory Approaches to Spanish Phonetics and Phonology, ed. Manuel Díaz-Campos, 48-61. Somerville, MA: Cascadilla Proceedings Project.

gap between vocalic sounds either real or virtual. The authors point out that the epenthetic vowel is inserted for articulatory reasons and it shows formants similar to /e/.

There has been little research on the acoustic nature of the vocalic sound that has been found in consonant clusters formed by stop + flap in Spanish. Furthermore, the clusters formed by stop + lateral or those formed by /f/ + flap or lateral, in which an intervening vocalic element may also be found, have not been extensively examined: the characterization of the vocalic sound in comparison to the full vowel are essential for clarifying whether the sound is an epenthetic vowel or whether it is part of the flap, as Massone suggests. In a study of the Spanish vibrants, as produced by two male speakers of Castilian Spanish, Blecua (2001) did not find a correlation between the duration of the vocalic element and voicing, place or manner of articulation, stress, or quality of the full vowel.

In terms of perception of the Spanish consonant clusters, Widdison (2004) tested the perceptual awareness of vowels in CC and C+liquid (CL) contexts by native Spanish speakers. In his study, the duration of the vowel between the two consonants was digitally manipulated by cutting down 3-4 glottal pulses. The duration of the epenthetic vowel in the test words ranged from 78ms to 0ms. The task consisted of identifying which word was played from quasi-minimal pairs such as *Atalas* 'tie-imperative 2 sing.' and *atlas* 'atlas'. The results of this study show that listeners tend to recognize very short vowel sounds (around 17 ms) in the CC context (the cutting recognition rate was 50%), whereas in the CL context the vowel was not reported below 27 ms. The author concludes that the CL context is propitious for the erroneous perception of a vowel due to the vocalic-like characteristics that it has. Nonetheless, the perception of the epenthetic vowel itself has not been tested.

This paper aims to provide an acoustic and a perceptual characterization of the vocalic element. With regards to the acoustic characteristics, it describes the epenthetic in terms of the duration and the frequency of the formants and compares these properties to those of the full vowel in near minimal pairs where there is no consonant cluster. It will take into account not only clusters formed by stop + flap but also those formed by stop + lateral and /f/ + flap or lateral. The study will examine the influence of the following factors on the occurrence rate and the quality of the vowel:

1. place of articulation of the stop or /f/
2. presence of a flap versus presence of a lateral in the cluster
3. voicing of the onset element of the cluster
4. position of the cluster with respect to the stressed syllable in the word (pre-tonic, tonic or post-tonic)
5. quality of the nucleic vowel
6. manner of articulation of the onset element (occlusive or approximant)

In the area of perception this paper assesses whether native Spanish speakers are aware of the presence/absence of the epenthetic vowel by using an accentedness-perception test.

2. Acoustic characterization of the epenthetic vowel

This study analyzes the acoustic characteristics of the vocalic element in consonant clusters. In addition, it examines the linguistic factors that influence the rate of occurrence of the vocalic element in natural speech.

2.1. Method

2.1.1. Selection of words

The words used in this study were selected in near minimal pairs, with the first word containing a cluster and the second word containing two full vowels. The cardinal vowels /a e i o u/ were taken into account and only tauto-syllabic clusters that are phonologically possible in Spanish were used; that is, clusters involving the occlusives /p t k b d g/ and the fricative /f/, plus the alveolar flap /ɾ/ or the lateral /l/. Non-existent words were used where it was not possible to find a real word that had the properties needed. The pairs were varied according to the six factors listed in section 1 and the distribution was as follows (the number between parentheses represents the number of pairs):

1. bilabial (13), labiodental (6), dental (13), or velar (11)
2. flap (24) or lateral (19)
3. voiced (18) or voiceless (25)
4. pre-tonic (13), tonic (18), or post-tonic (12)
5. /a/ (11), /i/ (10), /u/ (10), /e/ (6), or /o/ (6)
6. approximant (37) or fricative (6)

The full list of words can be found in the appendix. In addition, 14 distracter words were included for a total of 100 words (43 pairs + 14 distracters).

2.1.2. Consultants

In order to identify the geographical extension of the epenthetic vowel, the speech production of consultants from different countries of Latin America was analyzed. All of them were adult native speakers of Spanish; two females (C1F, from Colombia, 33 years old; and C2F, from Mexico, 25 years old), and three males (C3M, from Colombia, 31 years old; C4M, from El Salvador, 40 years old; and C5M, from Peru, 28 years old). None of the consultants reported having any speech or auditory difficulties.

2.1.3. Recording procedure

The 100 test words were randomly divided into four groups of 25 words each in order to facilitate the reading task. Each word was embedded in a carrier sentence such as *repita __ normalmente* "repeat __ normally." The consultants were asked to read the words once in a natural manner. The consultants were recorded using a Sony cassette recorder, model TCM-453V, and a multidirectional lapel microphone. The cassettes were Type 1 normal bias.

2.2. Analysis procedure

The recordings were digitalized and analyzed using Praat 4.0.13 software (thanks to Paul Boersma and David Weenink, University of Amsterdam). The speech was low-pass filtered and digitalized at a sampling rate of 22050 Hz and the measurements were made from wide-band spectrograms. The frequency of the vocalic formants was measured in the middle of each segment to avoid the effect of the transitions between segments. Only instances where the epenthetic vowel could be clearly differentiated from the contiguous sounds were analyzed. The difference between various means was compared using one-way ANOVA tests or independent samples t-tests according to the number of means to be compared.

3. Results

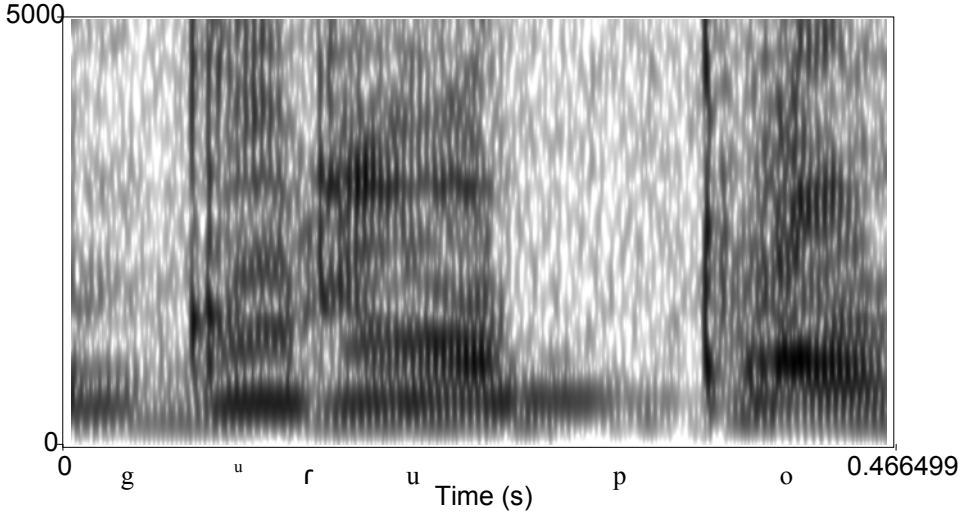
3.1. Duration of the epenthetic vowel

Figure 1 shows the spectrogram of the word *grupo* "group", as produced by consultant C1F. It is clear that the epenthetic vowel is an independent element and does not constitute part of the burst of the occlusive nor part of the following liquid.

It was not possible to identify an epenthetic vowel in all consonant clusters. In some cases, the spectrogram did not show a clear vocalic element due to overlap with a contiguous element. Another possibility is that the vowel was simply not produced for the word, which unfortunately cannot be proved or disproved.[1]

[1] The production of the epenthetic vowel was different among speakers; whereas some of them produced an epenthetic vowel in some words, other speakers did not. The inconsistency of occurrence of the epenthetic across consonant clusters and across speakers does not allow at this point a reliable multivariate analysis.

Figure 1. Spectrogram of *grupo* 'group' as produced by a native Spanish speaker.



The average duration of the identified epenthetic vowels and the full vowels is presented in Table 1, and the average duration of the pre- and post-flap or lateral full vowels of the non-cluster words is shown in Table 2.

The duration of the epenthetic constituted an average of 32% of the duration of the full vowel, while in the non-cluster words the two vowels were of approximately the same length. The vowel before a liquid (flap or lateral) was on average 24% shorter than the vowel after a liquid because the vowel in pre-liquid position was always in a non-stressed position, while the vowel in post-liquid position occurred in both stressed and non-stressed positions.

Table 1. Average duration of epenthetic vowel versus full vowel for cluster words

	Mean in ms	**SD**
Epenthetic vowel	26.98	8.79
Full vowel	85.61	22.97

Table 2. Average duration of a full vowel before and after a liquid in non-cluster words

	Mean in ms	**SD**
Full vowel before liquid	64.48	18.69
Full vowel after liquid	84.82	23.04

3.2. Influence of place of articulation

Table 3. Number of occurrences and average duration according to place of articulation

	No. of occurrences	**Duration**		
			Epenthetic	**Full**
Bilabial	39% (7/18)	mean in ms	26.49	86.96
		SD	5.94	19.57
Labiodental	25% (3/12)	mean in ms	19.71	70.85
		SD	5.89	24.06
Dental	78% (14/18)	mean in ms	25.81	90.02
		SD	8.03	26.89
Velar	43% (6/14)	mean in ms	33.91	81.87
		SD	11.43	18.13

Table 3 shows the number of occurrences and the average duration of the epenthetic and the full vowels according to the place of articulation of the first consonant of the cluster. A clearly greater number of epenthetic vowels occurred when the first consonant was dental as opposed to bilabial, labiodental or velar. However, a one-way ANOVA revealed no statistically significant differences in the average duration of the epenthetic according to the place of articulation of the first consonant, $F(3, 26) = 2.29$, $p = .102$.

3.3. Influence of flap versus lateral

As shown in Table 4, the number of occurrences of the epenthetic vowel is clearly higher when the cluster is formed with the flap than with the lateral (68% for the flap versus 25% for the lateral). Neither the duration of the epenthetic nor that of the full vowel seems to be affected by the type of liquid that forms the cluster (/r/ or /l/).

Table 4. Number of occurrences and average duration according to type of liquid

	No. of occurrences	**Duration**		
			Epenthetic	**Full**
/r/	68% (23/34)	mean in ms	28.61	87.60
		SD	9.08	23.15
/l/	25% (7/28)	mean in ms	21.61	79.35
		SD	13.59	22.95

An examination of the average duration of /r/ and /l/ in clusters and in non-clusters revealed no significant difference in the length of the liquids $t(28) = 1.08$, $p = .098$. This lack of difference supports the existence of an epenthetic element between the first consonant and the liquid: if no epenthetic element were present, we would expect a shorter liquid in clusters. In fact, Walsh and Parker (1982) point out that consonants are up to 30% shorter in consonant clusters than in non-clusters. Since the length of the liquids is the same whether they occur in a cluster or in an intervocalic position, we can assume that there is a vocalic element that intervenes between the first consonant and the liquid of the cluster. This finding argues against Massone's (1988) hypothesis that the epenthetic vowel is a vocalic component of the flap. If that were the case, it would be expected to find a difference between the length of the flap in clusters and in non-clusters.

Table 5. Average duration of /r l/ in clusters versus non-clusters

	Duration		
		Clusters	**Non-clusters**
/r/	mean in ms	23.45	26.79
	SD	6.05	7.07
/l/	mean in ms	57.62	68.52
	SD	17.46	22.95

3.4. Influence of voicing

The results in Table 6 indicate that there is a slightly higher occurrence rate of the epenthetic vowel when the first consonant of the cluster is voiceless than when it is voiced. However, this increase could be due to the fact that it is easier to identify a vocalic element in spectrograms when it occurs in the vicinity of a voiceless consonant than a voiced one because there is no overlap of the spectral energy of the two elements.

The duration of the epenthetic in clusters formed with a voiced initial consonant is significantly higher statistically, $t(28) = 4.28$, $p = .001$. This finding could be attributed to the difficulty in identifying the boundary between two contiguous voiced elements, even with the analysis of the formant transitions. However, a more detailed analysis on the voiced consonant + liquid is required.

Table 6. Number of occurrences and average duration according to voicing

	No. of occurrences	Duration		
			Epenthetic	**Full**
Voiced	42% (10/24)	mean in ms	34.66	87.86
		SD	8.01	24.97
Voiceless	53% (20/38)	mean in ms	23.13	84.43
		SD	6.40	22.47

3.5. Influence of stress

The position of the cluster with respect to the stressed syllable of the word appears to have no influence on the occurrence rate of the epenthetic, as shown in Table 7. The duration of the vowel in post-tonic position is significantly shorter statistically than in tonic position, $F(2, 27) = 3.45$, $p = .046$. However, the duration of the vowel in pre-tonic position was not statistically different from the tonic position. These findings are likely due to the effect of the edges, in which speakers tend to be more careful at the beginning of an elicitation and less careful towards the end.

Table 7. Number of occurrences and average duration according to stress

	No. of occurrences	Duration		
			Epenthetic	**Full**
Pre-tonic	45% (9/20)	mean in ms	27.15	74.02
		SD	5.64	20.40
Tonic	50% (12/24)	mean in ms	30.94	101.50
		SD	9.53	20.19
Post-tonic	50% (9/18)	mean in ms	21.52	74.83
		SD	8.15	16.01

3.6. Influence of the nucleic vowel

The epenthetic vowel occurs most frequently when the nucleic vowel is /a/, as shown in Table 8. The duration of the epenthetic is not statistically different among vowels, although it seems to be shorter when it occurs with /a/. The duration of the epenthetic is approximately one-third of the duration of the full vowel (24% for /a/, 36% for /u/, 40% for /i/, 28% for /e/, and 28% for /o/).

Table 8. Number of occurrences and average duration according to vowel.

	No. of occurrences	Duration		
			Epenthetic	**Full**
/a/	59% (13/22)	mean in ms	22.22	92.63
		SD	6.20	19.84
/i/	40% (8/20)	mean in ms	30.24	75.97
		SD	6.85	32.94
/u/	45% (9/20)	mean in ms	30.94	84.83
		SD	10.78	13.73
/e/	50% (3/6)	mean in ms	27.65	96.17
		SD	5.78	25.85
/o/	50% (3/6)	mean in ms	25.64	88.67
		SD	6.86	20.87

A one-way ANOVA conducted on the mean frequencies of the formants of the epenthetic vowel and the nucleic vowels /a/, /i/ and /u/[2] revealed no statistically significant differences, $F(3, 27) = 2.49$,

[2] For this statistical test, /a/, /i/ and /u/, the most distant vowels in the Spanish vocalic triangle, were chosen. Since formant frequencies have a wide range, the most distant vowels were deemed the most likely to present clear statistical differences if any.

p = .102. That is to say that the frequency of the formants of the vocalic element that occurs with /a/ is not statistically different from that of the formants of the full /a/. The same finding applied to /i/ and /u/. This similarity between the frequency of the epenthetic and the nucleic vowel suggests that the former is of the same quality as the nucleic vowel that follows it, in accordance with the rule of vowel harmony that causes new vowels to be similar to the closest strong nucleic vowel.

Table 9. Frequency of formants of the epenthetic vowel and full vowel.

		Frequency					
		Epenthetic			**Full vowel**		
		F1	**F2**	**F3**	**F1**	**F2**	**F3**
/a/	mean in Hz	703.86	1699.50	2872.12	763.38	1729.42	2675.39
	SD	214.68	467.56	255.09	82.60	240.48	306.78
/i/	mean in Hz	569.17	1944.00	3039.95	463.53	2157.12	2735.48
	SD	224.42	291.10	270.89	108.14	497.23	338.19
/u/	mean in Hz	641.68	1571.52	2814.96	469.74	1295.99	2694.44
	SD	169.51	377.15	261.98	83.04	201.56	557.05

However, when we graph the first and second formants of the epenthetic and the full vowels (Figure 2), we find that the epenthetic vowels appear in the central area of the Spanish vocalic triangle and approximate the schwa /ə/, although they tend slightly towards the nucleic vowel of the syllable. This small tendency may be enough to attribute the properties of the nucleic vowel to the epenthetic vowel. Another possibility is that the epenthetic is similar to a schwa with no real characteristics of the nucleic vowel, but it is perceived as similar to the nucleic vowel because of the post-cursor effect (Rosner & Pickering 1994). This hypothesis states that when an ambiguous item 'X' is located in a continuum within the vicinity of an unambiguous vowel 'V', an assimilation process occurs and X is perceived to be similar to V. Further analysis of the formants is necessary in order to determine the exact nature of the epenthetic vowel in relation to the cardinal vowels.

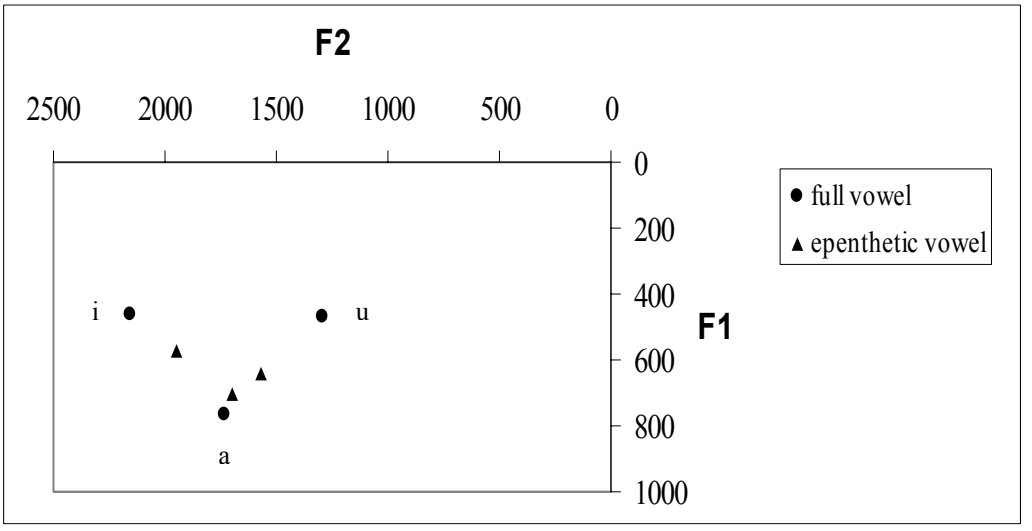


Figure 2. Graph of the epenthetic vowels in relation to the cardinal vowels

3.7. Influence of the manner of articulation

The epenthesis occurred twice as frequently when the cluster was formed with an occlusive than when it was formed with a fricative. Nonetheless, it is worth noting that the epenthetic vowel does appear with fricatives, a fact that has been largely ignored in previous literature. However, it was not possible to compare the duration of the epenthetic vowel with occlusives and with fricatives due to the small number of tokens in the latter group.

Table 10. Number of occurrences and average duration according to manner of articulation: occlusive, fricative.

	No. of occurrences	**Duration**		
			Epenthetic	**Full**
Occlusive	54% (27/50)	mean in ms	27.78	87.32
		SD	8.76	22.71
Fricative	25% (3/12)	mean in ms	19.71	70.85
		SD	5.86	24.06

4. Perception

The goal of the perceptual experiment is to investigate whether monolingual Spanish speakers perceive the absence/presence of the epenthetic vowel as assessed by an accentedness perception test.

4.1. Methodology

This study follows current trends in L2 research in assessing phonetic similarity using perceptual assimilation tasks. In these tasks, monolingual listeners are presented with speech stimuli, and asked to indicate to which L1 phonetic category each L2 token is most similar, and to rate its "goodness" as an exemplar of that category (Ingram & Park 1997, Flege et al. 1997, Strange 1999). Three different results may be obtained: a) an L2 sound is consistently categorized as a good instance of one L1 vowel (that is, consistently assimilated to one L1 vowel) and attains good ratings, b) an L2 sound is consistently assimilated to one L1 vowel but with poor goodness ratings, or c) an L2 sound is identified as instances of multiple L1 vowels with poor goodness ratings. These three alternatives correspond to the classification of L2 sounds as 'identical,' 'similar' and 'new', respectively, in Flege's (1987) equivalence classification hypothesis.

The target tokens were words containing tautosyllabic consonant clusters /p, t, k, b, d, g, f + l, r/ and they were selected from a 100 million word corpus of Spanish texts available online at (www.corpusdelespanol.org) thanks to Mark Davies of Brigham Young University. To control frequency, the words were drawn from among the first 150 entries containing the target consonant cluster. The linguistic variables that were taken into account are: voicing (voiced/voiceless), stress (pre-tonic/tonic/post-tonic positions) place and manner of articulation, the nucleic vowel (a, e, i, o, u) (165 possible cases), and duration of the epenthetic vowel (full epenthetic vowel, half epenthetic vowel, and no epenthetic vowel).

The tokens were recorded by a female native Spanish speaker in a soundproof room. The target tokens were inserted in a carrier sentence i.e. *diga* ___ *nuevamente* 'say ___ again'. The spectral analysis of the tokens revealed that the epenthetic vowel was not present in all the cases. Thus, only cases in which the epenthetic vowel was clearly differentiated from the surrounding segments were chosen (35 tokens). From those cases that clearly showed an epenthetic vowel we obtained the first duration variant: tokens with full epenthetic. For the second variant, half of the vowel was trimmed; cutting only in the middle of the vowel in order to maintain the transitions intact, resulting in the tokens with half epenthetic. For the third variant, the whole epenthetic vowel was deleted, resulting in the tokens with no epenthetic vowel. The number of tokens was 105 (35 X 3) plus 95 distracters for a total of 200 tokens.

For this experiment, a goodness judgment task using Praat was designed, which presented the participants with a scale from 1 to 7 and randomly played one of the words. The participants were asked to grade using the goodness of the token, where 1 is bad (affected speech) and 7 is good (natural speech). Once the participants ranked the goodness of the word a 0.8 second interval transcurred before the next word would play. The approximate time to complete the task was 30 minutes.

4.2. Participants

For this experiment the subjects were 65 first-year-university students in Colombia who voluntarily agreed to participate.

4.3. Results and Discussion
4.3.1. Results by cluster

Table 11. Results from Test of Within-Subject Effects

Cluster	**Mean**			**n**	**df (num/ den)**	**F**	**Sig**	**Observed Power**
	Without (V)	**Mid (V)**	**Complete (V)**					
kr	4.75	5.05	5.59	63	(2, 124)	7.584	.001*	.941
gr	5.0	5.95	6.11	62	(2, 122)	17.942	.000*	1.00
dr	6.03	5.19	6.08	62	(2, 122)	13.993	.000*	.998
tr	6.05	5.62	5.28	60	(2, 118)	4.104	.019*	.718
br	5.15	5.21	5.63	62	(2, 122)	2.699	.071	.526
pr	5.87	6.18	5.85	62	(2, 122)	2.181	.117	.439

* Statistically significant. Computed using alpha = .05

A repeated-measures ANOVA test of the clusters where the epenthetic has been altered (elided or cut in half) or left intact, shows a statistically significant difference in the perception of *kr*, *gr*, *dr*, and *tr*, whereas the clusters formed by bilabial + [r] -*br* and *pr*- were not statistically significant F(2, 122) = 2.699 ns; and F(2, 122) = 117 ns, respectively.

The mean values from the clusters *kr*, *gr*, and *dr* suggest that the test words with a complete epenthetic vowel are perceived as more native like/natural than the cases in which it is cut in half or elided. In contrast *tr* was perceived as more natural when the epenthetic was deleted, and less natural when it was complete, M = 6.05 and M = 5.28, respectively.

The data in Table 11 suggest that when the places of articulation of the elements of the cluster are farther away an epenthetic vowel is required (as a stepping stone), such as in the case of the velars [k, g] and the alveolar [r], whose places of articulation are further away than dentals and alveolars. When the places of articulation of the elements of the cluster are closer -as is the case with the dentals [t, d] and the alveolar [r]- we get mixed results. Between the dentals, the place of articulation of the dento-alveolar [d] is closer to [r] than [t]; this closer proximity requires an epenthetic vowel to enhance the distinguishability of the 2 elements. In the cluster *tr* the epenthetic seems not to be essential to delimit the two elements of the cluster.

In cases where the active articulator of the first element of the cluster is other than the tongue, there appears not to be need for a ‘stepping stone’ in the articulatory continuum. Thus, the epenthetic seems not to have a role in the perceptibility of the cluster.

4.3.2. Duration of the epenthetic by cluster

Paired-samples t tests were conducted to identify which of the three variants of duration were assessed to be different. The analysis of each cluster (Table 12) shows that in the clusters *kr*, *gr*, and *tr*, there is significant difference between cases with complete and without epenthetic vowels t(62) =

3.936, p<.05; t(61) = 4.886, p<.05; and t(59) = 2.772, p<.05, respectively. The perception of accentedness in cases in which the epenthetic is cut in half is statistically different from full and no epenthetic in the clusters *kr*, *gr*, *dr* but not in *tr* where only the presence or absence of the epenthetic is significantly different. These results suggest that native Spanish speakers perceive the presence/absence of the epenthetic and even smaller changes such as cutting the epenthetic in half; considering that the average duration of the epenthetic is 26.98 ms, the reduction to one half (approx. 13.5ms) would fall under the accepted perceptibility duration of about 30 ms.

Table 12. Paired samples t-test analysis of duration in each cluster

Cluster	Pair	Mean	T	df	Sig (2-tailed)
kr	without – mid	-.302	-1.291	62	.202
	without – complete	-.841	-3.936	62	.000*
	mid – complete	-.540	-2.590	62	.012*
gr	without – mid	-.952	-4.451	61	.000*
	without – complete	-1.113	-4.886	61	.000*
	mid – complete	-.143	-.943	62	.350
dr	without – mid	.841	4.406	62	.000*
	without – complete	-.048	-.323	61	.748
	mid – complete	-.887	-4.110	61	.000*
tr	without – mid	.429	1.710	62	.092
	without – complete	.767	2.772	59	.007*
	mid – complete	.333	1.256	59	.214

* Statistically significant. Computed using alpha = .05

4.3.3. The Interaction of variables

The analysis of the relation of the phonetic variables considered here (place of articulation, voicing, stress) shows that the perception of accentedness in consonant clusters does not depend exclusively on the duration of the epenthetic vowel. A two-way within-subjects analysis of variance was conducted to evaluate the effect of the phonetic variables on the duration of the epenthetic. Table 13 shows that the interaction of duration and place of articulation is highly significant F(4, 236) = 3.871, p<.05, with an observed power = .895. These results support our proposal that when the places of articulation of the first and the second element of the cluster are either farther away or too close together, the epenthetic vowel serves as a boundary element that permits differentiation between them.

Table 13. Tests of Within-Subjects Effects Duration X Place of articulation

	df (num/den)	F	Sig.	Observed Power
Duration	(2, 118)	15.907	.000*	.999
Place of articulation	(2, 118)	14.146	.000*	.998
duration * place of articulation	(4, 236)	3.871	.005*	.895

* Statistically significant. Computed using alpha = .05

A two-way within-subjects analysis of variance shows that the effect of the voicing of the first element of the cluster on the assessed accentedness of tokens with different epenthetic duration is marginally significant (Table 14), F(2, 122) = 2.95, p = .056.

Table 14. Tests of Within-Subjects Effects Duration X Voicing

Source	df (num/ den)	F	Sig.	Observed Power
Duration	(2, 122)	18.402	0.000*	1.000
Voicing	(1, 61)	5.813	0.019*	0.660
duration * voicing	(2, 122)	2.951	0.056	0.565

* Statistically significant. Computed using alpha = .05

The effect of stress on assessed accentedness due to the epenthetic's duration (Table 15) is highly significant $F(4, 224) = 3.728$, $p<.05$. However, further research on the distance of the cluster with respect to the accented syllable is required.

Table 15. Tests of Within-Subjects Effects Duration X Stress

Source	df (num/ den)	F	Sig.	Observed Power
Duration	(1, 122)	16.064	0.000*	0.999
Stress	(2, 122)	47.682	0.000*	1.000
duration * stress	(4, 244)	3.728	0.006*	0.882

* Statistically significant. Computed using alpha = .05

A two-way ANOVA test to evaluate the effect of the phonetic factors together shows an interaction of the highest level (duration, stress, and place of articulation). The interaction is highly significant $F(4, 224) = 5.367$, $p<.05$; these results support the composite nature of the perception of epenthetic vowels.

Table 16. Tests of Within-Subjects Effects Duration X Stress X Place of Articulation

	df (num/ den)	F	Sig.	Observed Power
Duration	(2, 112)	9.413	.000*	0.976
Stress	(2, 112)	11.131	.000*	0.990
Place of articulation	(1, 56)	3.847	.055	0.487
duration * stress	(4, 224)	4.670	.001*	0.946
duration * place of articulation	(2, 112)	5.7560	.004*	0.859
stress * place of articulation	(2, 112)	33.096	.000*	0.999
duration * stress * place of articulation	(4, 224)	5.366	.000*	0.971

* Statistically significant. Computed using alpha = .05

The sensitivity to accentedness in cases where the epenthetic has been manipulated in real words indicates that the phonetic clues are perceived prior to the activation of the lexical information. It has been shown that a listener's phonotactic patterns help in word recognition in the first language (Church 1987, Frauenfelder & Lahiri 1985, Kabak 2003). For instance, English speakers may find illicit consonant clusters after the schwa-deletion phenomenon. Thus, words like *tomato* become [tmato] after the schwa deletion, originating the sequence *tm*, which is not allowed in English. However, the knowledge of the English lexicon can be used to recover the vowel, leading to the correct recognition of the word *tomato* (Kabak 2003). In the case of the Spanish consonant clusters, the manipulation of the epenthetic results in the perception of accentedness by native speakers and their knowledge of the lexicon helps to recognize the words.

5. Conclusions

Until recently, the epenthetic vowel was considered to be an element of affected, emphatic speech. The results of this study indicate that it occurs far more frequently and that it can be found in natural speech as well. Moreover, it is not limited to clusters formed by an occlusive and a flap, but also occurs with the fricative /f/ and with the lateral /l/. The following properties of epenthetic vowels were observed in the data from this study:

- The duration of the epenthetic is approximately one-third of the full vowel.
- The epenthetic vowel occurs more frequently when the first consonant of the cluster is dental than when it is bilabial, labiodental or velar. However, its duration does not seem to be affected by the place of articulation of the first consonant.
- More epenthetic vowels occur when the cluster is formed with the flap than with the lateral, but the length of the vowel is not affected by the type of liquid used in the cluster.
- The length of the liquids does not vary significantly in clusters and in intervocalic positions, thereby supporting the presence of an epenthetic vocalic element between the first consonant and the liquid in clusters.
- The epenthetic vowel seems to occur more frequently when the first consonant of the cluster is voiceless, although this finding may be attributed to the increased ease of identification of the boundaries. Likewise, it appears to be longer after a voiced consonant, but again this finding may be due to identification problems since it is more difficult to determine the boundary between two voiced elements.
- The position of the cluster with respect to the stressed syllable of the word does not have any influence on the number of occurrences of the epenthetic vowel. The edges appear to affect its length in that the vowel is shorter in post-tonic position.
- The epenthetic vowel seems to occur more frequently when the nucleic vowel is /a/ and it also appears to be shorter in this context. At the moment, there are no obvious indications as to why this is the case.
- Its occurrence is much more frequent when the cluster is formed with an occlusive than when it is formed with a fricative.
- From a perceptual point of view, monolingual Spanish speakers perceive affectedness in words where the epenthetic vowel has been manipulated (cut in half or elided completely) in the clusters *kr*, *gr*, *dr*, and *tr*.

-The results show that the place of articulation has an effect on the perception of the epenthetic. When the first element of the cluster is velar or dental, the alteration of the epenthetic is more perceptible. In the case of bilabials, the results show no statistically significant difference in perception of cases with a complete, mid or no epenthetic vowel.

-The data suggest that voicing of the first element of the clusters has a marginal effect on perceptibility of the duration of the epenthetic.

-The stress of the syllable in which the cluster occurs also has an effect on the perception of the length of the epenthetic, but at this point more research on this area is needed.

-These preliminary results suggest that, in the case of Spanish, the epenthetic vowel has the function of perceptually enhancing the cluster; however more research on the area is required.

-The interaction of several factors in the perceptibility of the epenthetic vowel demonstrates its composite nature. Research is currently underway to more closely identify the ranking of phonetic clues in the perception of the epenthetic vowel.

-In future research, further exploration into the correlation between production and perception of Spanish consonant clusters is needed. Similarly, the duration at which the epenthetic is perceived is also deserving of greater attention.

This study presents evidence that there is not isomorphism between speech perception and speech production. Further research on the production and perception of the svarabatic vowel is necessary in order to identify whether the role of the epenthetic vowels in Spanish consonant clusters is to break tautosyllabic CC sequences or for articulatory reasons.

Appendix

blindado			
contabilidad	vértebrum	atlas	pácurus
	táburus	átala	sucrus
platal			
palatal	dirigido	Sumatra	flirteo
	escudriñar	alcántara	filigrana
capricornio			frustrado
pirineo	trujillo	glisemia	enfuruñarse
	turumillo	anguilizado	
bravo			Flandes
barado	podría	aclimatado	falange
	pediría	kilimanjaro	
blanco		cruzado	péteflun
balando	atlántico	curumaní	gónfulun
	talante		
planta		gurú	sofrito
palanca	estrado	grupo	zafirito
	tarado		
Prusia	vidrio	mezclado	Biáfara
arampurú	adórdiris	poco calado	cifra
diablus	cuadrus	Anglés	
discóbulus	cándurus	Anguilis	

References

Blecua, Beatriz. 2001. *Las vibrantes del español: manifestaciones acústicas y procesos fonéticos*. Doctoral Dissertation. Universitat Autònoma de Barcelona.

Boersma, Paul and David Weenink. 2005. *PRAAT: Doing phonetics by computer*, version 4.3.04. Online at <http://www.praat.org>.

Church, Ken. 1987. Phonological parsing and lexical retrieval. *Cognition* 25.53-70.

Davies, Mark. Online Corpus of Spanish. Online at <www.corpusdelespanol.org>.

Flege, James. 1997. The role of phonetic category formation in second-language speech formation. *New Sounds 97. Proceedings of the Third International Symposium on the Acquisition of Second Language Speech*, ed. by Jonathan Leather and Allan James, 79-88. Klagenfurt:University of Klagenfurt.

Flege, James, Ocke-Schwen Bohn, and Sunyoung Jang. 1997. Effects of experience on non-native speakers' production and perception of English vowels. *Journal of Phonetics* 25:4.437-470.

Frauenfelder, Ulrich and Aditi Lahiri. 1985. Understanding words and word recognition: Does phonology help? *Lexical representation and process*, ed. by William Marslen-Wilson, 319-341. Cambridge, MA: MIT Press.

Guirao Miguelina and María Garcia. 1991. Los perfiles acústicos y la identificación de /l/ /r/. *Revista argentina de lingüística* 7:1.21-42.

Ingram, John and See-Gyoon Park. 1997. Cross-language vowel perception and production by Japanese and Korean learners of English. *Journal of Phonetics* 25.343-370.

Kabak, Baris. 2003. *The perceptual processing of second language consonant clusters.* Doctoral Dissertation. University of Delaware.

Malmberg, Bertil. 1965. *Estudios de fonética hispánica* (translated by Edgardo Palavecino). Madrid: Instituto Miguel de Cervantes.

Massone, Maria. 1988. Estudio acústico y perceptivo de las consonantes nasales y líquidas del español. *Estudios de fonética experimental* 3.15-34.

Navarro, Tomás. 1963. *Manual de pronunciación española*. New York: Hafner Publishing Co.

Quilis, Antonio. 1981. *Fonética acústica de la lengua española*. Madrid: Gredos.

Rosner, Burton and John Pickering. 1994. *Vowel perception and production*. Oxford: Oxford University Press.

Strange, Winnifred. 1999. Levels of abstraction in characterizing cross-language phonetic similarity. *Proceedings of the 14th International Congress of Phonetic Sciences*, ed. by John Ohala, Yoko Hasegawa, Manjari Ohala, Daniel Granville and Ashlee Baily, 2513-2519. Berkeley, CA: University of California.

Walsh, Thomas and Frank Parker. 1982. Consonant cluster abbreviation: An abstract analysis. *Journal of Phonetics* 10: 423-437.

Widdison, Kirk. 2004. Perceptual awareness of vowel fragments appearing in Spanish Cr and CC environments. Paper presented at Laboratory Approaches to Spanish Phonology, Indiana University, Bloomington, Indiana, Sep. 17-18, 2004.

Selected Proceedings of the 2nd Conference on Laboratory Approaches to Spanish Phonetics and Phonology

edited by Manuel Díaz-Campos

Cascadilla Proceedings Project Somerville, MA 2006

Copyright information

ISBN 1-57473-411-3 library binding

Ordering information

Orders for the library binding edition are handled by Cascadilla Press.
To place an order, go to www.lingref.com or contact:

Cascadilla Press, P.O. Box 440355, Somerville, MA 02144, USA
phone: 1-617-776-2370, fax: 1-617-776-2271, e-mail: sales@cascadilla.com

Web access and citation information

This entire proceedings can also be viewed on the web at www.lingref.com. Each paper has a unique document # which can be added to citations to facilitate access. The document # should not replace the full citation.

This paper can be cited as:

Ramírez, Carlos Julio. 2006. Acoustic and Perceptual Characterization of the Epenthetic Vowel between the Clusters Formed by Consonant + Liquid in Spanish. In *Selected Proceedings of the 2nd Conference on Laboratory Approaches to Spanish Phonetics and Phonology*, ed. Manuel Díaz-Campos, 48-61. Somerville, MA: Cascadilla Proceedings Project.

or:

Ramírez, Carlos Julio. 2006. Acoustic and Perceptual Characterization of the Epenthetic Vowel between the Clusters Formed by Consonant + Liquid in Spanish. In *Selected Proceedings of the 2nd Conference on Laboratory Approaches to Spanish Phonetics and Phonology*, ed. Manuel Díaz-Campos, 48-61. Somerville, MA: Cascadilla Proceedings Project. www.lingref.com, document #1325.