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CONSONANT CLUSTERS AND RHOTIC VARIATION IN COSTA RICAN SPANISH[1]

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ABSTRACT. This study examines the phonetic realization of consonant clusters involving the alveolar tap (/Cɾ/ and /ɾC/) in Costa Rican Spanish, a variety known for rhotic variation. It addresses two main questions: (1) What factors contribute to phonetic variation in these clusters (e.g., syllable structure, place of articulation, voicing)? (2) What affects the transition time between consonants? Results show greater rhotic variation in heterosyllabic clusters and homorganic environments (e.g., /kaɾne/ → [kaɻne]). Consonant transition durations are longer in tautosyllabic clusters than in heterosyllabic clusters. An interesting finding is that intensity measures indicate that the tap is more constricted in heterosyllabic /ɾ.C/ clusters and less so in tautosyllabic /Cɾ/ clusters. These findings challenge traditional views of lenition based on strong (onset) vs. weak (coda) positions; I suggest a coarticulatory explanation.

Keywords: consonant clusters; rhotics; phonetic variation; intrusive vowel; Costa Rican Spanish

RESUMEN. Este estudio examina la realización fonética de los grupos consonánticos que involucran la consonante vibrante simple alveolar (/Cɾ/ y /ɾC/) en el español de Costa Rica, una variedad conocida por su variación fonética en las róticas. Se abordan dos preguntas principales: (1) ¿Qué factores contribuyen a la variación fonética en estos grupos (por ejemplo, estructura silábica, punto de articulación, sonoridad)? (2) ¿Qué afecta el tiempo de transición entre consonantes? Los resultados muestran una mayor variación rótica en los grupos heterosilábicos y en entornos homorgánicos (por ejemplo, /kaɾne/ → [kaɻne]). Las duraciones de transición consonántica también son mayores en los grupos homorgánicos. Un hallazgo interesante es que las mediciones de intensidad indican que la vibrante simple tiene más constricción en los grupos heterosilábicos /ɾ.C/ que en los tautosilábicos /Cɾ/. Estos hallazgos cuestionan las visiones tradicionales de la lenición basadas en posiciones fuertes (ataque) vs. débiles (coda); para esto, sugiero una explicación coarticulatoria.

Palabras clave: grupos consonánticos; róticas; variación fonética; vocal intrusiva; Español de Costa Rica

1. Introduction

The Spanish sounds classified as 'rhotics' have received great attention due to their complex distribution. Most studies about rhotics in Spanish today propose two separate

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phonemes (e.g. Hualde, 2014), namely an alveolar tap /ɾ/ and an alveolar trill /r/. The usual description is that the trill /r/ is realized in word initial position (e.g., [ˈro.xo] *rojo* 'red'), after a heterosyllabic consonant (e.g., [on.ˈraɾ] *honrar* 'to honor'), and intervocalic position (e.g., [ˈka.ro] *carro* 'car'). The alveolar tap /ɾ/ is also realized in intervocalic position (e.g., [ˈka.ɾa] *cara* 'face'), in coda position – both internally (e.g. [ˈkaɾ.ta] *carta* 'letter') and word finally [e.g., [a.ˈmaɾ] *amar* 'to love') – and in onset clusters (e.g. [ˈpɾi.mo] *primo* 'cousin') (Bradley 2019, Hualde 2014). In that sense, the trill and the tap are only contrastive in intervocalic position, while in all other contexts the two sounds are in complementary distribution. This study follows the assumption that both sounds constitute separate phonemes in Spanish.

The tap/trill distribution in Spanish is more complex as phonetic variation is present across dialects (Lipski 2012; Campos-Astorkiza 2012). One particularly interesting case is Costa Rican Spanish. For example, Chavarría Aguilar (1951) proposed a different phonemic inventory for this variety, composed of the phonemes /ɾ/ and /ř/ - with the latter described as an apico-alveolar groove spirant, tense and very fricative, as opposed to the trill found in other varieties. There is phonetic variation for the tap /ɾ/ as well: in addition to the tap [ɾ], a retroflex approximant [ɻ], a trill [r], and a quasi-affricate in /tɾ/ clusters have all been previously reported for this dialect (e.g., Quesada Pacheco and Vargas Vargas 2010; Vásquez Carranza 2006; Salazar Rodó 2022).

One context in which we find the tap is consonant clusters, which can occur in either linear order (both /Cɾ/ and /ɾC/). /Cɾ/ represents *tautosyllabic* clusters, in which both elements belong to the same syllable as a complex onset (e.g., [ˈbɾaso] *brazo* 'arm'), and /ɾC/ represents *heterosyllabic* clusters, in which both elements belong to separate syllables – the tap is the coda of a syllable and the following consonant represents the onset of the following syllable (e.g., [ˈaɾ.bol] *árbol* 'tree'). Phonetically, a tap is a voiced sound in which the tip of the tongue makes a ballistic occlusion on the alveolar ridge (Hualde 2014, Blecua & Cicres 2018, Bradley 2019). It is acoustically realized as a (nearly) silent period but with f0 presence. However, the articulatory movement does not always involve full constriction between the articulators, and therefore the tap might show frication and/or formants during the constriction phase (Blecua & Cicres 2018; Warner & Tucker 2018). The constriction of the tap may vary depending on the type of consonant cluster in which it occurs. For example, Kim and Repiso-Puigdelliura (2020) examined tap production in /Cɾ/ and /ɾC/ clusters produced by Spanish heritage speakers. Their intensity measures showed that taps in /Cɾ/ clusters were more constricted than those in /ɾC/ clusters, suggesting that cluster type influences the degree of tap constriction.

Additionally, the production of the tap in consonant clusters may result in a phonetic intrusive vowel[2] which has been argued to represent a period of vocal opening in the transition of the two consonants (e.g., Bradley 2019, Blecua & Cicres 2018). This intrusive vowel is short in duration and has formants but has no role in the phonology of Spanish. It is phonetically realized when vocal tract opening occurs in between the articulation of the consonants, meaning the period between the offset of the first consonant and the onset of the second consonant in the sequence (e.g., [kᵊɾema] *crema* 'cream'). Massone (1988) argues that the nature of the tap in the consonant cluster is that of a single vibration which is formed by an intrusive vowel followed by an

[2] I use the term intrusive vowel; however, these vocalic elements have also been referred in the literature as 'epenthetic vowel', 'excrescent vowel', 'schwa insertion', 'excrescent schwa' or 'svarabhakti vowel'. Later in the paper, I will use a different term (Transitional Period) to refer to the period of time between the two consonants, from the offset of the first consonant to the onset of the second consonant, and not only the element with visible formants.

occlusion, which implies that the intrusive vowel is consistently realized and a natural inherent part of the consonant cluster. However, in cases in which /ɾ/ is realized as a different element phonetically, as is the case of the retroflex approximant in the aforementioned Spanish variety, there is no separate intrusive vowel given the different articulatory nature of the retroflex approximant. For example, Costa Rican Spanish speakers may realize the word *carne* 'meat' as [kaɹ.ne], where an intrusive vowel is not observed between the rhotic and an adjacent consonant, given that the articulation of the rhotic as an approximant in the cluster does not correspond to a brief occlusion period as in a canonical tap.

While different studies have examined rhotics (both tap and trill phonemes) in the Costa Rican Spanish dialect and reported that there is phonetic variation for both, we require a more robust understanding on how neighboring consonants and syllable structure influence the realization of the tap /ɾ/ in consonant clusters. For example, the extent to which the two different types of clusters (tautosyllabic [Cɾ] or heterosyllabic [ɾ.C]) show phonetic variation in the tap realization is not fully known. Also, the extent to which the place of articulation of the neighboring consonants (consonants articulated with the same/different articulators) as well as their voicing quality, influence tap /ɾ/ variation is also unclear. For example, the extent to which the [n] in *carne* influences the realization of the rhotic as a retroflex approximant is not very clear. Additionally, the intrusive vowel observed in the consonant cluster when a tap is produced with occlusion, as opposed to an element that has a different articulatory nature such as a retroflex approximant, has received almost no attention in this particular Spanish variety.

This study contributes to the understanding of the Spanish /ɾ/ production as a component of consonant clusters in Costa Rican Spanish spoken in Central Valley of the country. The study focuses on two main goals. The first goal is to determine what the phonetic realization of the tap /ɾ/ in consonant clusters of Costa Rican Spanish is (both from a categorical and a gradient point of view), and to determine what properties of the consonant clusters affect this phonetic variation (type of cluster – tautosyllabic [Cɾ] vs heterosyllabic [ɾC] –, place of articulation of the neighboring consonant and/or its voicing). The results seek to not only expand our knowledge of the overall tap variation in this Spanish variety by providing an analysis based on acoustic information, but also aims to contribute to our understanding of consonant cluster production using quantitative methods to determine the different production patterns. The second goal is to examine the intrusive vowel produced by vocal tract opening followed by the brief occlusion of the tap, and to determine whether some components (if any) of the cluster influence the transition time between the two consonants. This information will provide further acoustic insights not only on the articulatory nature of the tap in the consonant clusters (i.e., whether the intrusive vowel is consistently realized as a result of the gesture coordination), but it will also provide evidence on whether certain phonetic elements present in the consonant cluster influence how these speakers acoustically realize the transition of the two consonant gestures in the cluster.

This paper is organized as follows. Sections 1.1. and 1.2. provide an overview of the main components under investigation, including the critical consonant clusters in Spanish, and the phonetic variation reported for Costa Rican Spanish. A summary of the methodology used is presented in section 2. The main results of the study, including the tap /ɾ/ phonetic variation and the duration measures of the consonant clusters, are summarized in section 3. A discussion of the main findings and their implications for our understanding of tap /ɾ/ in consonant clusters is provided in section 4. Finally, section 5 provides a conclusion summarizing the key findings of this study.

1.1. Spanish Alveolar Tap and Consonant Clusters

The Spanish tap /ɾ/ occurs in two types of consonant clusters. The first of these types is consonant clusters in which both consonants are in an onset sequence /CɾV/[3]; i.e., they belong to the same syllable (henceforth, tautosyllabic). The second is heterosyllabic clusters; that is, the tap and the adjacent consonant are separated by a syllable boundary (i.e., /Vɾ.C/ sequences in which the tap corresponds to a coda and the following consonant represents the onset of the following syllable). In both cases, the cluster might be voiced/voiceless homorganic in which both consonants share the same place of articulation (e.g., voiced = [ˈ**dɾ**e.no] *dreno* 'I drain'; voiceless = [ˈ**tɾ**e.se] *trece* 'thirteen'), or a voiced/voiceless heterorganic in which the place of articulation of the neighboring consonant is different from that of the tap (e.g., voiced = [ˈ**bɾ**a.so] *brazo* 'arm'; voiceless = [ˈ**kɾ**a.neo] *cráneo* 'skull'). In some varieties of Spanish, it has been already indicated that the place of articulation of the neighboring consonant may affect the phonetic realization of /ɾ/; for instance, homorganic clusters predict assibilation of /ɾ/ in Highland Ecuadorian Spanish in [ɾt] clusters (Bradley 2004), and in [tɾ] clusters of Chilean Spanish and Costa Rican Spanish (Candia et al., 2010; Vásquez Carranza 2006; Dearstyne 2021).

As mentioned above, the production of the consonant clusters evidences an intrusive vowel between the offset of one consonant and the onset of the following one (Bradley 2019, Blecua & Cicres 2018). These intrusive vowels show vowel formants but have no role in the phonology of the language; in other words, the intrusive vowels do not repair any syllabic structure and are invisible to the phonology (Hall 2006), although Romero (2008) indicates that the presence of the intrusive vowel facilitates the speakers' perception of [ɾC] clusters. Generally, these intrusive vowels have been analyzed as the result of the gesture coordination in the articulation of the consonant sequence which leaves an intergestural interval in the form of vowel intrusion (e.g., Bradley 2007). It has also been reported that the intrusive vowel resulting from the articulatory coordination of the consonants is highly variable in duration (Schmeiser 2006; Schmeiser 2020), and we require further insights on whether and how certain phonetic elements of the cluster influence the period of time in the articulatory transition of the consonants. One element that seems to be a predictor in the intrusive vowel's length is the voicing feature of the neighboring consonant: for [Cɾ] clusters, longer intrusive vowels are found in clusters in which both consonants are voiced (Schmeiser 2006; Schmeiser 2020), while a longer intrusive vowel is found in [ɾC] sequences when the consonant is voiceless (Schmeiser 2006). In other words, a voiced consonant neighboring the tap in the [Cɾ] sequence may impact the transition between the consonants resulting in a longer vocal-tract-opening period of time, while in the [ɾC] consonants this seems to happen when the consonant is voiceless instead. Lexical stress has also been said to be a predictor of the intrusive vowel's duration; it seems that stressed syllables correlate with longer intrusive vowels, while unstressed syllables evidence shorter transition times (Schmeiser 2006). However, while the intrusive vowels may indeed be influenced by the phonetic factors of the cluster, such predictors are highly variable across Spanish dialects, as certain predictors seem more consistent in some dialects than others (Schmeiser 2006; Schmeiser 2020).

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[3] In Spanish, there is also a [C.r] (e.g., *honrar* [on.raɾ] 'to honor' sequence in which the trill is found post-consonantally but both consonants are separated by a syllable boundary. This cluster is not examined in this study.

To summarize, there are two different types of clusters in Spanish that involve the /ɾ/; tautosyllabic clusters in which the two consonants are in the same syllable, and clusters in which the two consonants are separated by a syllable boundary (heterosyllabic). In addition, the realizations of the clusters, including the intrusive vowel found in the transition of the consonants, may be influenced by different components of the cluster, such as the place of articulation and voicing of the consonant adjacent to the tap /ɾ/.

1.2. Variation in realization of /ɾ/ in Costa Rican Spanish

The rhotic sounds (/r/ and /ɾ/) of Costa Rican Spanish have been a topic of interest because of their phonetic variation (e.g., Quesada Pacheco and Vargas Vargas 2010; Vásquez Carranza 2006; Salazar Rodó 2022). This paper specifically addresses /ɾ/ variation in consonant clusters. In tautosyllabic clusters /Cɾ/, most of the phonetic variations, such as fricative and approximant segments, has been reported for homorganic clusters (clusters in which the two sounds are produced using the same articulators), while heterorganic clusters generally are reported to show a tap [ɾ] realization – one in which there is a brief occlusion on the alveolar ridge. For the /tɾ/ sequence, in particular, some authors report that the cluster is produced as an alveolar affricate due to assimilation of the tap with the previous consonant (Chavarría Aguilar 1951; Agüero Chaves 2009). Other authors report assibilation in the tap of the /tɾ/ sequence (transcribed as [tř̥]) (Quesada Pacheco and Vargas Vargas 2010; Vásquez Carranza 2006; Salazar Rodó 2022). Additionally, Vásquez Carranza (2006) reports a voiced alveolar affricate in the /dɾ/ sequence (transcribed as [dř]) but only when the sequence is in the onset of the stressed syllable, and it is preceded by [l] or [n] (/tendɾia/ → [tenˈdřia]). For Calvo Shadid (1995), the tap is the most frequent variant, followed by a fricative and an approximant. It is important to point out that most of these descriptions of Costa Rican Spanish rhotics are based on impressionistic analysis. Dearstyne (2021) and Salazar Rodó (2022) are perhaps the only studies that include acoustic analysis of rhotics (both /r/ and /ɾ/) in Costa Rican Spanish. Both authors show that there is variation in the phonetic realization of /ɾ/ in the tautosyllabic homorganic clusters, as it is produced as a tap, a fricative or an approximant; in other words, there are three different variants for /ɾ/. For Dearstyne (2021), the fricative realization for /ɾ/ is confined to clusters with a voiceless coronal, i.e., /tɾ/, although there is variation across speakers and speech style, as the fricative is restricted to spontaneous speech in Dearstyne's study, not appearing in formal tasks like read speech. On the other hand, the intrusive vowels that constitute part of the clusters have received almost no attention in studies of Costa Rican Spanish. Dearstyne (2021) points out the presence of an intrusive vowel in both heterorganic and homorganic clusters, although this author does not provide extensive information on their phonetic realization.

Heterosyllabic clusters /ɾC/ also show phonetic variation in the production of /ɾ/ in Costa Rican Spanish. Agüero Chavez (2009) reports that /ɾ/ might be realized as a fricative in heterosyllabic clusters. Dearstyne (2021) and Aguilar Porras (2014) report a retroflex approximant [ɻ] before dental and alveolar consonants – the latter author indicates that voiced consonants trigger most of the variants. A trill has also been reported but it has been said that it is reserved to formal or read speech, and rarely in spontaneous speech (Dearstyne 2021), which suggests that certain production patterns might be related to different production tasks. This suggests that such phonetic variations for the tap /ɾ/ are indeed influenced by place of articulation of the neighboring consonant, as well as their voicing and/or the type of production task, but this should be further examined with a concise quantitative approach.

Similar to the tautosyllabic clusters, little is known about the intrusive vowels in the heterosyllabic clusters of Costa Rican Spanish. Vásquez Carranza (2006), who examines rhotics in general in Costa Rican Spanish, indicates that the intrusive vowel evidenced in Standard Spanish is not evidenced in her data, even in the case where no coarticulation occurred (i.e., realizations in which /ɾ/ was produced with a different articulatory gesture, such as in the affricate /tɾ/ reported above), although this should be carefully interpreted as no acoustic analysis was carried out. Additionally, Vásquez Carranza (2006) reports that the tap tends to be deleted in heterosyllabic clusters when the tap precedes an enclitic (e.g., *comerlo* /komeɾlo/ → [ko.ˈme.lo]; *tomárselo* /tomaɾselo/ → [to.ˈma.se.lo]). Most authors agree that in consonant clusters, the most frequent realization of the rhotic is that of a tap, although Dearstyne (2021) claims that the tap is an approximant gesture as closure is rarely complete.

These examples illustrate that there is phonetic variation in dialectal /ɾ/ production. Once again, it is important to point that almost all studies about Costa Rican Spanish have been based on impressionistic data, and a full understanding of its phonetic characteristics requires analysis of carefully designed acoustic data.

In summary, in this paper I collect and analyze acoustic data on /ɾ/ in Costa Rican Spanish. With these data we are enriching the base of empirical work on Costa Rican Spanish, and Spanish varieties more generally. Because some variants of tap, as well as the transition between the elements of the cluster, have been previously reported to be conditioned by characteristics of adjacent consonants, we focus on clusters in this study, to tease apart these contextual factors with quantitative data.

2. Methods

The materials and data collection for this study were approved by the Stony Brook University Institutional Review Board. Recordings were made in Costa Rica in December of 2023 and January of 2024. The following sections provide details about participants (section 2.1.), materials and data collection (section 2.2.), and data segmentation (section 2.3.) and statistical analysis (section 2.4.).

2.1. Participants

Nine speakers from the Central Valley participated in the study. All the speakers were females, ages 26-62. From now on, I refer to these speakers as "Costa Rican Spanish" (CRS) speakers. All CRS participants grew up and resided in the Central Valley region of Costa Rica, and all participants had college education, and are considered middle class Costa Ricans. All participants had some knowledge of English as this is a very common second language in the Costa Rican education system. Due to technical problems with the audio recordings, data from one speaker were not analyzed, and therefore, not reported. Therefore, this results in a total of 8 CRS speakers. All participants completed a consent form before beginning the recordings and did not receive a compensation for their participation.

2.2. Materials and Data Collection

A word list was recorded to elicit tautosyllabic and heterosyllabic consonant cluster productions in four different conditions: 1) voiced homorganic (hence VDHOMO) (e.g.

[ˈdɾe.no] *dreno* 'I drain', [ˈveɾ.de][4] *verde* 'green'), voiceless homorganic (hence VSHOMO) (e.g. [ˈtɾe.se] *trece* 'thirteen' [ˈaɾ.te] *, arte* 'art') voiced heterorganic (hence VDHETE) (e.g. [ˈbɾa.so] *brazo* 'arm', [ˈjeɾ.be] *hierve* 'it boils') and voiceless heteroganic (hence VSHETE) (e.g., [ˈkɾa.neo] *cráneo* 'skull', [ˈbaɾ.ka] *barca* 'boat'). Three words per condition and per cluster type were elicited (therefore, 24 words were tested; 12 words in the tautosyllabic cluster and 12 words in the heterosyllabic cluster). The words were elicited in the carrier phrase "*En español,* _____ *es una palabra*" (*In Spanish,* _______ *is a word*). Each word was inserted in the carrier phrase and each carrier phrase was projected individually on a screen in front of the speaker, and the speaker read the list of words three different times, resulting in 72 cluster production by each speaker; 36 in tautosyllabic clusters and 36 in heterorganic clusters. The order of the words in all three lists was randomized. To maintain as much homogeneity as possible for optimal comparisons and avoid a possible stress-influence factor in the results (Schmeiser 2006), all target /ɾ/s appeared in a stressed syllable (e.g., [ˈkɾa.neo] *cráneo* 'skull', [ˈbaɾ.ka] *barca* 'boat'). 12 words containing other Spanish rhotics in other contexts were also included in the word list (e.g., intervocalic trill, intervocalic tap, etc.) although they were not analyzed for the purposes of this study. Finally, 24 different words were included as distractors. See Appendix 1 for the complete list of words. Each list of words, meaning the three different list repetitions, were randomized and presented in different orders. Participants were instructed to read at a comfortable natural reading pace.

The data collection occurred in a quiet room in a library. A unidirectional condenser microphone was placed 5-10cm in front of the speakers' mouth, and recordings were made directly into Praat (Boersma & Weenink 2025) with a sampling rate of 44.1kHz.

2. 3. Data Segmentation and Acoustic Measures

The consonant clusters – in addition to the /ɾ/'s adjacent vowel – were segmented in Praat (Boersma & Weenink 2001) by two trained assistants using visual inspection of spectrograms. The trained assistants are undergraduate students at Stony Brook University; they have taken both Phonetics and Experimental Phonetics courses, and they have a basic knowledge of Spanish, though this was not required for the phonetic segmentation task. The goals of segmentation were to delimit the boundaries of the /ɾ/ realization, for automatic duration and intensity measures in Praat, and to delimit the transition that occurred between the realization and the adjacent consonants. This transitional period between the offset of a consonant and the onset of the adjacent one will henceforth be referred to as TP. All segmentations were done in a visible window of approximately 500ms. Later, in order to do a categorization of /ɾ/ productions, the author labeled each /ɾ/ realization using the criteria listed in Table 1. Overall, the main visual cues consist of formants, release bursts, zero crossings in the waveforms criteria and the intensity contour. There were five main categories that derived organically in the cluster productions. Three fall under the tap gesture umbrella – True Tap (TT), Fricative Tap (FT), and Approximant Tap (AT) –, in which there is an intrusive vowel in between the tap realization and the neighboring consonant. The other two correspond to other categories and have a different articulatory nature: an approximant element in which there is no clear intrusive vowel transition in between the consonants (labeled as Retroflex Approximant (RA) as it was auditorily retroflex, and to maintain consistency

[4] In most varieties of Spanish, voiced stops /b d g/ are produced as approximants ([β ð ɣ]) after [ɾ]. However, Costa Rican Spanish is different as stops are produced in all post-consonantal contexts including tap [ɾ] (Carrasco 2008; Carrasco et al., 2012).

with previous proposals, although the exact place of articulation in unknown), and a trill in which there are two or more intrusive vowels, each followed by a brief (almost) silent period suggesting occlusion.

True Tap (TT)	**Fricative Tap (FT)**	**Approximant Tap (AT)**	**Retroflex Approximant (RA)**	**Trill**
1. Presence of ONE intrusive vowel between the two consonants 2. Lack of visible formants throughout the consonant 3. Relatively large difference in intensity in relationship to neighboring vowel(s) 4. Presence of a release burst (optional)	1. Presence of ONE intrusive vowel between the two consonants 2. Lack or weak formants throughout the consonant 3. Relatively small difference in intensity in relationship to neighboring vowel(s) 4. High frequency noise	1. Presence of ONE intrusive vowel between the two consonants 2. Presence of formants throughout the consonant 3. Relatively small difference in intensity in relationship to neighboring vowel(s) 4. No release burst	1. No presence of intrusive vowel between the two consonants 2. Presence of formants throughout the consonant 3. No clear drop/raise in intensity in relationship to neighboring vowel 4. Drop of higher formants	1. Presence of TWO OR MORE intrusive vowels with silent/weak periods in between

Table 1. Criteria for categorization of /ɾ/ productions in the consonant clusters.

Figure 1 shows a spectrographic example of both the segmentation of the elements and the labels given to the tokens according to the visual cues. Figure 1 (a-c) correspond to those considered tap gestures (AT, TT, FT), in which there is a transitional period that contains an intrusive vowel in between the consonants. Additionally, according to the author's perceptual judgement and visual cues (change in formant structure, multiple occlusions, etc.), tokens like Figure 1 (d-e) were considered non-tap productions. Figure 1 (f) shows the segmentation between the release burst of the first consonant, and the onset of the tap; the red arrow illustrates the moment in which formants are observed, which shows that this TP may be bigger than the period with formants only.

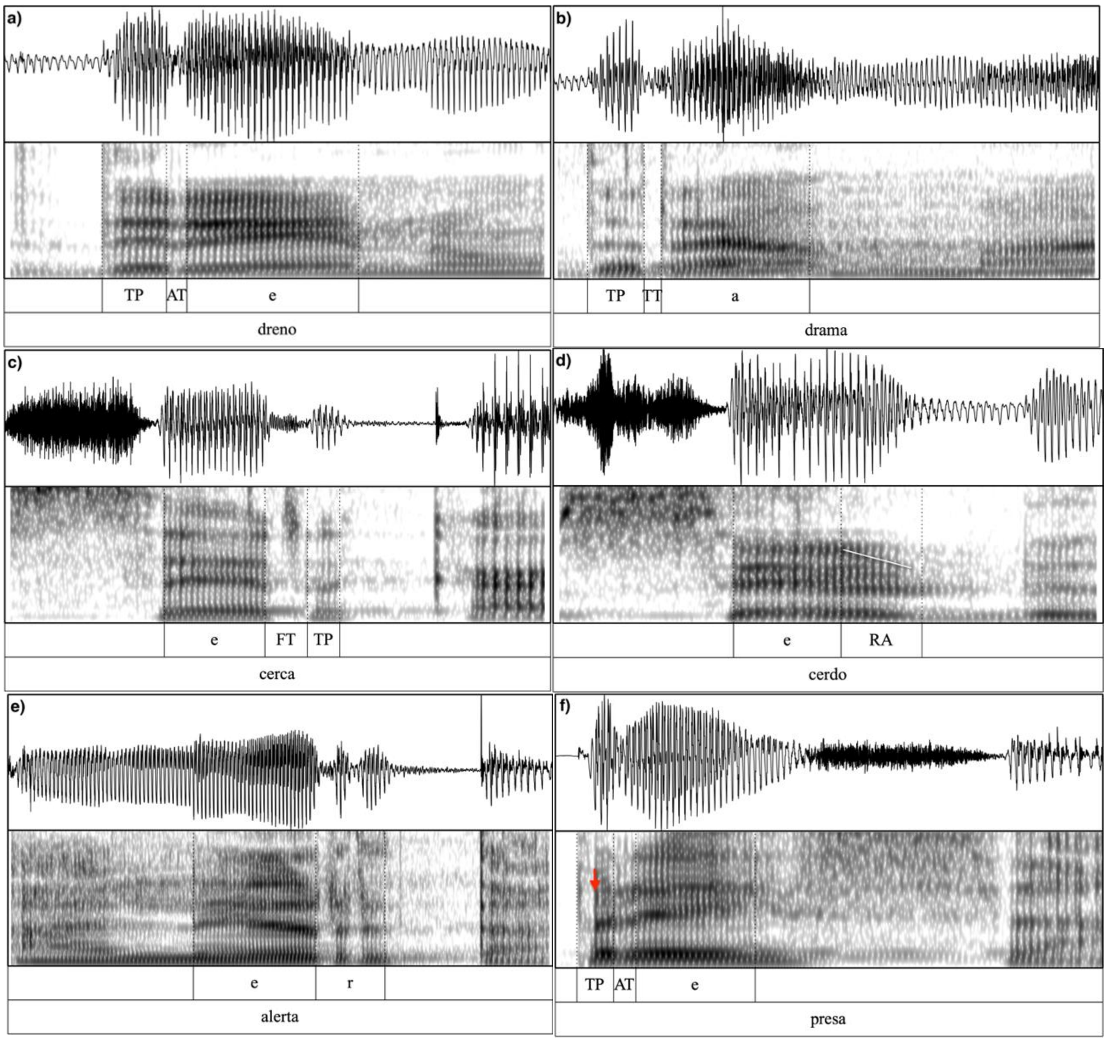

Figure 1. Categorization of /ɾ/ productions. **a)** Approximant Tap (AT). **b)** True Tap (TT). **c)** Fricative Tap (FT). **d)** Retroflex Approximant (RA). **e)** Trill (r). **f)** Transitional Period (TP)

In order to look at the duration of the elements in both consonant clusters, the durations were normalized for the TP, the tap and the vowel. Normalized durations of the TP+Tap+Vowel interval in both types of clusters (/CɾV/ and /VɾC/) were computed to control for speech rate effects on raw durations. This was done by calculating the proportion of the sounds' duration in the cluster sequence, rather than providing the raw duration measures (e.g., Ramus et al., 1999). First, the raw durations were normalized for each sequence production, and then averaged by condition and by speaker. Then, by using the formula below (1), the duration of each element was calculated as a percentage of the total whole TP+Tap+Vowel and Vowel+Tap+TP intervals. The raw duration of the segment divided by the sum of the whole sequence, provides a number from 0 to 1 that corresponds to the proportion of the whole sequence (e.g., 0.22 corresponds to 22% of the sequence) for each segment type (tap, vowel, or TP).

(1) Segment

Sequence sum (TP + ɾ + V ***OR*** V + ɾ + TP)

Finally, given that those elements categorized as tap gestures (TT, AT and FT) may differ in a continuous or gradient way, and that there might be a cluster type (/Cɾ/ vs /ɾC/) effect on the taps' degree of constriction (Kim and Repiso-Puigdelliura 2020), an intensity measure was employed to better understand any patterns that might exist within the categories used in the labelling analysis. The intensity of the tap realizations was measured by looking at the intensity difference between the tap and the neighboring vowel (following vowel in /CɾV/ sequence, and previous vowel in /VɾC/ sequence), as done in previous studies (Warner and Tucker 2011; Kim and Repiso-Puigdelliura 2020). The tap's intensity minimum was subtracted from the neighboring vowel's intensity maximum. The result represents the degree of the intensity drop/raise, shown in decibels. The higher the number, the greater the difference in the intensity, which in turn suggests a higher level of lingual constriction. The lower the number, the weaker the segment, implying less constriction.

Once the segmentation had been marked in Praat by the two assistants and checked by the author, and the categorization of the tokens was done based on the visual cues in the spectrogram, Praat scripts were used to compute the durations of each labelled segment, as well as to extract the intensity values for the tap and the vowel in the same syllable. All data was first computed for each speaker and then averaged across all speakers per group according to the different conditions of the clusters.

2.4. Statistical Analysis

In order to determine whether distribution of the /ɾ/ categorical realizations (i.e., [ɾ], [r], etc.) is dependent on the cluster conditions (e.g., VD_HETE, VS_HOMO, etc.), a Chi-Square Test of Independence was carried out for both tauto- and heterosyllabic clusters. Given that the type of realizations is greater in the /ɾC/ cluster, and therefore the number of the realizations are more scattered, the chi-square test was run based on 1000 replicates for the /ɾC/ cluster.

In addition, to examine the effects of cluster type (/Cɾ/ and /ɾC/), voicing, and syllabification (HETE and HOMO conditions) on the acoustic measures of intensity and duration (i.e., transitional period), two linear mixed-effects models were fit, one for each measure using the lme4 package in R (Bates et al., 2015). Each model included cluster type, voicing, and syllabification as fixed effects, and random intercepts for both word and speaker were included to account for variability associated with lexical items and individual talkers. I first specified a model with a three-way interaction between the fixed factors; because none of the interaction terms reached significance, I reduced the model in a stepwise fashion, refitting the models with only two-way interactions, and then again with only main effects. Final reported models include only main effects.[5] Post-hoc pairwise comparisons were done using the emmeans package (Lenth, 2021) with Tukey adjustment for multiple comparisons.

[5] lmer(Acoustic measure ~ cluster type + voicing + syllabification + (1|talker) + (1|word))

3. Results

3. 1. Categorical realizations of /ɾ/

Our first goal was to determine the range of phonetic realizations of the /ɾ/. Figure 2 and Table 2 show the distribution of /ɾ/ productions across all CRS speakers, as determined by visual inspection of spectrograms.

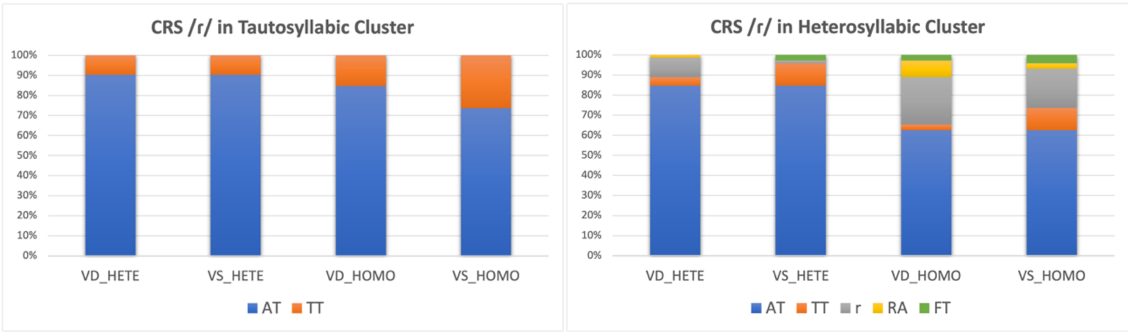

Figure 2. /ɾ/ realizations across all CRS speakers per cluster type, based on spectrographic visual cues.

Cluster	Condition	AT	TT	Trill	RA	FT
Tautosyllabic (/ɾ/ in onsets)	VD_HETE	65 (SD 1.13)	7 (SD 1.13)	0	0	0
	VS_HETE	62 (SD 0.89)	10 (SD 0.89)	0	0	0
	VD_HOMO	61 (SD 1.51)	11 (SD 1.51)	0	0	0
	VS_HOMO	53 (SD 2.45)	19 (SD 2.45)	0	0	0
Heterosyllabic (/ɾ/ in codas)	VD_HETE	60 (SD 1.20)	3 (SD 0.74)	7 (SD 1.36)	1 (SD 0.35)	0
	VS_HETE	61 (SD 1.19)	7 (SD 1.13)	1 (SD 0.35)	0	2 (SD 0.46)
	VD_HOMO	45 (SD 1.92)	5 (SD 1.06)	14 (SD 2.49)	6 (SD 1.16)	2 (SD 0.71)
	VS_HOMO	45 (SD 3.38)	8 (SD 2.07)	14 (SD 2.71)	2 (SD 0.71)	3 SD 0.74)

Table 2. Summary (number of tokens) of /ɾ/ realizations across all CRS speakers per cluster type. Standard deviations reported in parenthesis.

For all conditions and both cluster types, the predominant realization is an approximant tap (AT) – one in which there is a tap gesture but formants are observed during the constriction. True tap (TT), in which full constriction is evidenced in the acoustics, is slightly more often realized in the homorganic clusters, (average 20.8%) than in the heterorganic clusters (average 9.72%), and it is mainly observed in the tautosyllabic cluster. For the /tɾ/ clusters in particular, no productions of /tɾ/ involved an affricate, unlike what had been reported in other studies (e.g., Dearstyne 2021; Vásquez Carranza 2006). In the heterosyllabic clusters (coda /ɾ/), however, there is more variation. For all conditions, AT remains as the predominant variant and TT is produced in fewer instances. After the AT and TT, the trill [r] is the most common realization, particularly in both voiced and voiceless homorganic clusters (21.5% on average). The retroflex approximant realization surfaced in a few instances, mostly in voiced homorganic clusters, in words like *carne* ‘meat’ and *cerdo* ‘pork’. Finally, some tap gestures showed high frequency noise similar to that of a fricative, so those were labeled as fricative tap (FT). Most of the FT were produced in the homorganic clusters, on an average of 3.5%.

Table 3 shows the results of the chi-square test of independence. The p-values indicate that there is a statistically significant association between the sound variant realized and the cluster conditions, both for the tautosyllabic cluster (p = 0.045) and the heterosyllabic cluster as well (p = 0.001).

z	X-squared	df	p-value
/Cɾ/	8.009	3	0.045
/ɾC/	32.16	NA	0.001

Table 3. Results of the Chi-squared of Independence to test the distribution of the production realizations per cluster type. For the /ɾC/, the test was run based on 1000 replicates.

3.2. Transitional Period (TP) in the cluster transition

The second goal of this study was to determine the presence of the Transitional Period and to examine whether there are some (if any) predictors in the consonant clusters for its duration.[6] The results – in Figure 4 – show that the transitional period (TP) between the two consonants tends to be longer than the tap constriction. In the [CɾV] sequences, there is more duration variation in the TP across speakers (SD = 0.041) than in the [VɾC] sequence (SD = 0.013). In addition, in both cluster types, the average TP in the voiced homorganic condition is longer than in the other conditions, though the difference is slight.

[6] Recall also that normalized durations were computed as the percentages of the full TP+Tap+Vowel interval in both clusters (/CɾV/ and /VɾC/), in order to control for possible differences in speech rate across speakers.

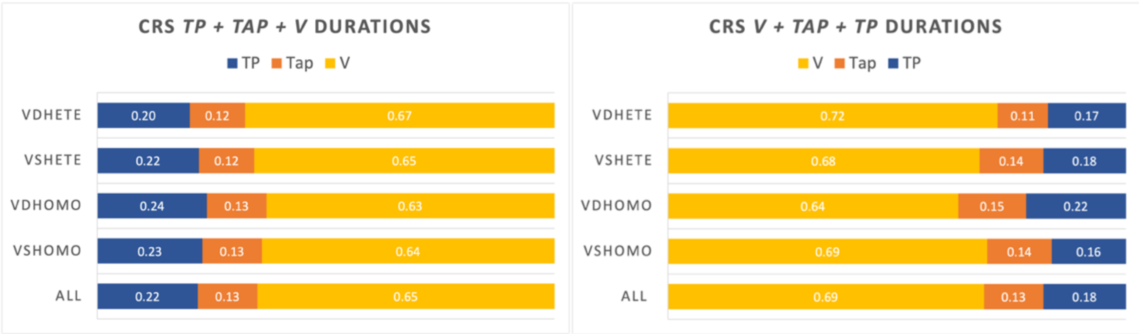

Figure 4. Normalized duration of *TP* + *Tap* + *Vowel* and *Vowel* + *Tap* + *TP* intervals across all CRS speakers.

The final main effects model for TP showed a significant effect of cluster type, with TPs in the /ɾC/ cluster shorter than TPs in the /Cɾ/ cluster (β = -.03, p < .001). Voicing showed a trend toward longer TP durations for voiced segments (β = .01, p = .08), and place of articulation was not significant (β = .002, p = .83). Pairwise comparisons aligned with these patterns and are shown in Table 4.

Contrast	Estimate	SE	df	t.ratio	*p*-value
/Cɾ/ - /ɾC/	-0.0531	0.0128	24.2	-4.161	0.0003
VD - VS	0.0223	0.0121	31.3	1.834	0.0762
HETE - HOMO	0.00265	0.0125	26.4	0.212	0.8339

Table 4. Results of Linear Mixed Model testing pairwise comparison for TP duration.

3.3. Intensity measures of the tap gestures (AT, TT and FT)

Finally, in order to compare the tap [ɾ] realization in the two types of clusters (where the tap appears in onset and in coda positions), the intensity measures were analyzed for those elements categorized as tap gestures (AT, TT and FT); in other words, excluding trills (r) and retroflex approximants (RA). Figure 6 shows the intensity difference between the tap gestures in the tautosyllabic cluster (tap in onset) and heterosyllabic cluster (tap in coda) for all contexts. These results show that coda taps (in the /VɾC/ sequence) are more constricted (bigger intensity difference), on average, for all conditions across all speakers than those in the onset clusters (/CɾV/), contrary to the findings in Kim and Repiso-Puigdelliura (2020) where onset taps in the /Cɾ/ cluster were more constricted than coda taps in the /ɾC/ cluster.

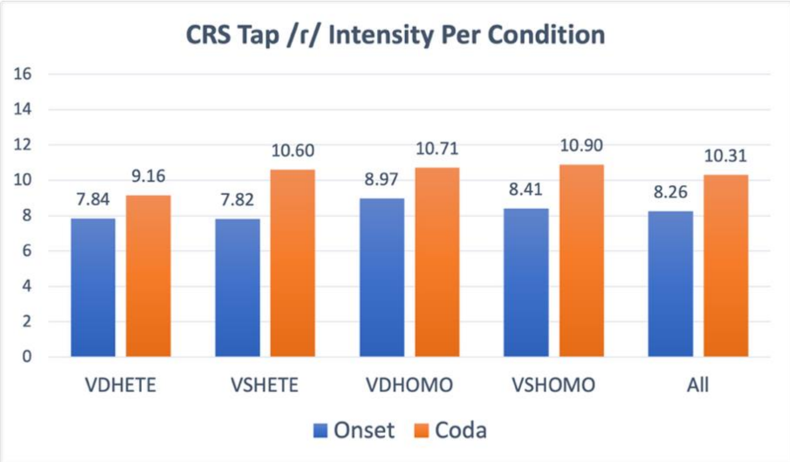

Figure 6. Intensity differences per condition, separated by C voicing and place.

The onset versus coda difference holds consistently. The mean intensity difference in onset vs coda pooled for all four conditions is 2.05dB. The difference is greater in the voiceless heterorganic clusters (2.78 dB) and smaller in the voiced heterorganic clusters (1.32 dB). The results of the final main effects model showed significant effects of cluster type and place of articulation but not voicing for the intensity measure. Codas had higher intensity difference than onsets (β = .97, p < .001), and HETE clusters had lower intensity difference than HOMO clusters (β = -.42, p = .04); there was no effect of voicing (β = -.31, p = .12). Post-hoc pairwise comparisons aligned with these results and are shown in Table 5.

Contrast	Estimate	SE	df	t.ratio	p-value
/Cɾ/ - /ɾC/	1.95	0.393	22.9	4.949	0.0001
VD - VS	-0.623	0.388	24.5	-1.605	0.1214
HETE - HOMO	-0.844	0.39	23.5	-2.163	0.0410

Table 5. Results of Linear Mixed Model testing pairwise comparison for tap/vowel intensity difference.

4. Discussion

The main goal of this study was to examine the production of the phonemic /ɾ/ as a component of consonant clusters in Costa Rican Spanish. Regarding the realization of /ɾ/, the categorical labeling shows that overall, most taps occur as a brief occlusion in which formants are observed; this suggests that full constriction is often not achieved in its production. This patterns with previous proposals that assume that the tap is an approximant gesture (Dearstyne 2021; Blecua & Cicres 2018; Warner & Tucker 2018). It is also clear that heterosyllabic clusters exhibit more different types of /ɾ/ realizations than tautosyllabic clusters. In tautosyllabic clusters, at least in this relatively formal task, there is generally a tap gesture, but which level of occlusion occurs depends on factors like the place of articulation of the neighboring consonant. For example, homorganic tautosyllabic clusters show more constricted taps (categorized as TT). This might be explained by the fact that full constriction is required for the previous occlusive consonant involving the tip of the tongue, and therefore there is a phonetic effect of the previous occlusion that also affects the tap gesture. Heterosyllabic clusters, on the other hand, exhibit more different types of /ɾ/ realizations, including what would be considered different articulatory targets. Recall that trill and retroflex approximant productions make up as much as 35.19% of /ɾ/ realizations, particularly in homorganic clusters. As suggested by Blecua and Cicres (2018), those elements with no evidence of a TP correspond to more weakened variants (i.e., retroflex approximants as in *carne*), while trills that have two or more occlusions are the result of a strengthening process. One possible explanation as to why /ɾ/ undergoes weakening or strengthening processes in these particular contexts (homorganic clusters) is to increase the phonetic distinction of the consonants, as this is the optimal discrimination scenario for the listener (Saporta 1955). In other words, the tap may be realized either as a trill or as a retroflex approximant in order to be phonetically different from [t] and [d], which are also sounds produced by a contact made by the tip of the tongue on the alveolar ridge. This might seem contradictory as those elements that do not correspond to weakened or strengthened variants (i.e., those produced as tap gestures) correspond to the majority of the realizations of the tap /ɾ/ in these homorganic clusters in the /ɾC/. However, as mentioned above, Romero (2004) states that while the intrusive vowel has no role in the phonology, the presence of the intrusive vowel may be beneficial for the perception of the [ɾC] sequence.

Several production patterns previously proposed for /ɾ/ in Costa Rican Spanish were not evidenced in this study. For instance, there was no evidence of the articulatory blending of the /tɾ/ sequences producing affricativized clusters, as observed in (Quesada Pacheco and Vargas Vargas 2010; Vásquez Carranza 2006; Salazar Rodó 2022). Additionally, there were also very few realizations of the retroflex approximant also previously reported (Dearstyne 2021; Aguilar Porras 2014). This suggests that certain realizations of Costa Rican Spanish /ɾ/ realizations are, perhaps, confined to spontaneous speech, and speakers will make use of the more standard variants (variations of a tap gesture) in careful speech, as in a reading task. Therefore, the fact that the predominant production for all contexts in this careful task is that of a tap gesture supports the idea that a tap production in which there is a brief occlusion on the alveolar ridge is the canonical variant for Costa Rican Spanish.

The second main goal of the study was to determine the existence of a transitional period in between the consonants, how this transition period in the consonant sequence is realized acoustically in this dialect, and also to determine what elements in the cluster seem to contribute to such duration. The results show that there is a very consistent production of a TP across all conditions. First, the results confirm that the duration of the TP tends to be variable across speakers, and the TP tends to be longer than the actual tap constriction, confirming previous results (Bradley 2019; Schmeiser 2006 and 2020). Schmeiser 2020 claimed that a longer intrusive vowel is evidenced in a cluster in which both members share the same voicing quality. In this study, the results show such trend as well, in which clusters that have voiced consonants tend to show longer TPs than clusters that have a voiceless consonant. Place of articulation, on the other hand, does not seem to play a role, as TPs are not bigger/shorter based on their HETE or HOMO condition. Finally, the consistent and systematic appearance of a TP in the cluster productions suggests that there is very little articulatory overlap in the coordination of these consonants in Costa Rican Spanish. In other words, when the consonant sequence is articulated, there is a period of vocalic opening which results from the moment in which the first constriction has been ended and the second has not yet been completed. This, however, needs to be confirmed with articulatory evidence. The consistent appearance of a TP also confirms that the nature of the tap in the cluster is that of a single vibration which is formed by an intrusive vowel followed by an occlusion (Massone 1988).

It was also found that the tap-vowel intensity difference in both types of clusters patterned in a way that raises questions about the notion of strong versus weak syllabic positions in lenition. Lenition has been defined as a reduction in the constriction degree of a consonant (Kirchner 2001, Odden 2013). Furthermore, some authors have proposed a strong-weak scale based on positional factors, suggesting that certain phonological environments favor lenition more than others. For example, it has been proposed that onset position ({#,C}_ (word initial position) and VC._V (post-coda onset)) are strong positions in which more constriction is generally achieved, and coda position (_{C,#} (both internal and final codas)), as well as V_V (intervocalic) are weak positions in which lenition is most likely to occur (Ségéral and Scheer 2008, Szigetvari 2008). Following this line of argument, we should predict that the tap in the heterosyllabic cluster [ɾC] will be a weak one, particularly as compared to that of the onset cluster [Cɾ]. The results from this study show an opposite pattern in which the tap is more constricted in the heterosyllabic cluster and weaker in the onset cluster. I argue that the intensity difference in both clusters is explained by a coarticulatory effect. The tap sound is weaker preceding a vowel which requires almost no articulatory constriction, and it is more constricted before a consonant, in which articulatory constriction is required. Thus, at this phonetic level, the realization of tap in the /VɾC/ sequence is in a (phonetic) strengthening position due to an anticipatory coarticulation of a following more constricted sound.

5. Conclusions

To conclude, this study has contributed to the understanding of the phonetic realization of the Spanish /ɾ/ as a component of consonant clusters in Costa Rican Spanish. First, the results suggest that the tap – at least in Costa Rican Spanish – is rarely produced with full occlusion, as vowel formants are often/regularly evidenced during the constriction phase. Second, phonetic variation of /ɾ/ was conditioned by the syllabic position in the cluster; i.e., tap was produced with more phonetic variation in the heterosyllabic clusters than in the tautosyllabic ones. Additionally, homorganic clusters, in which the neighboring consonant shares the same place of articulation as that of the tap, show more phonetic variation in the tap than heterorganic clusters, once again, particularly in the heterosyllabic clusters. The results in the relatively formal task examined in this study also suggest that the tap (whether it is AT, TT or FT) is the most frequent production in Costa Rican Spanish, as opposed to other realizations reported by previous authors such as the affricate production for /tɾ/ which were not evidenced in our results, or the retroflex approximant which was produced in very few instances. This suggests that while a true tap may be the most frequent realization in more careful speech styles in Costa Rican Spanish, the other realizations reported elsewhere may be confined to spontaneous speech. Additionally, our results show evidence of a transitional period that contains an intrusive vowel in between the two consonants of the cluster, which was not reported on previous impressionistic studies of Costa Rican Spanish. This TP is variable in duration and tends to be longer than the tap occlusion, which patterns with the intrusive vowels reported for other Spanish varieties. This confirms that the nature of the tap in the consonant cluster corresponds to both an intrusive vowel and an occlusion phase (Massone 1988).

The intensity measures of those tokens categorized as tap show an interesting pattern regarding the constriction of the tap in both clusters. The tap tends to be more constricted in the heterosyllabic [ɾC] cluster (where the tap is in coda) and less constricted in the tautosyllabic [Cɾ] (where the tap is in onset); this finding challenges the notion of weak vs strong positions in lenition. However, I argue that this pattern is due to coarticulation, in which the tap becomes more constricted when preceding an occlusive consonant. To conclude, this study has contributed to the understanding of the Spanish tap /ɾ/ production in consonant clusters by these Costa Rican Spanish-speaking populations. Future research should investigate these consonant clusters in spontaneous speech, as these results might be dependent on task type.

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References

Aguilar Porras, E. (2014). La ocurrencia de la aproximante retrofleja ante consonantes dentales y alveolares en estudiantes universitarias de la Universidad Nacional. *Revista De Lenguas Modernas*, (20). Retrieved from: https://archivo.revistas.ucr.ac.cr/index.php/rlm/article/view/14972

Agüero Chaves, A. (2009). El español de Costa Rica. Costa Rica: Editorial UCR.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 1-48. https://doi.org/10.18637/jss.v067.i01

Blecua, Beatriz & Jordi Cicres. 2018. "Rhotic variation in Spanish codas" In *Romance Phonetics and Phonology*, Ed. by Juana Gil and Mark Gibson. Oxford: OUP. https://doi.org/10.1093/oso/9780198739401.003.0002

Boersma, Paul & Weenink, David (2025). *Praat: doing phonetics by computer* [Computer program]. Version 6.4.27, retrieved 27 January 2025 from http://www.praat.org/

Bradley, Travis (2019). Spanish rhotics and the phonetics-phonology interface. In *The Routledge handbook of Spanish phonology* (pp. 237-258). Routledge. https://doi.org/10.4324/9781315228112-13

Bradley, Travis (2007). Spanish complex onsets and the phonetics-phonology interface. *Optimality-theoretic studies in Spanish phonology*, 15-38. https://doi.org/10.1075/la.99.02bra

Bradley, T.G. (2004). Gestural timing and rhotic variation in Spanish codas. In T. Face (Ed.), *Laboratory Approaches to Spanish Phonology* (pp. 197-224). Berlin, Germany: Mouton de Gruyter.

Calvo Shadid, Annette. (1995). Variación fonética de /ɾ/ y /r/en el habla culta de San José. *Revista de filología y lingüística de la Universidad de Costa Rica*, 21(1), 115- 134. https://doi.org/10.15517/rfl.v21i1.20266

Campos Astorkiza, Rebeka. (2012*). The phonemes of Spanish. The handbook of Hispanic linguistics*, 89-110. https://doi.org/10.1002/9781118228098.ch5

Carrasco, Patricio (2008). An acoustic study of voiced stop allophony in Costa Rican Spanish (Order No. 3337717). Available from ProQuest Dissertations & Theses Global. (304605865).

Carrasco, Patricio & Hualde, José Ignacio & Simonet, Miquel (2012). Dialectal differences in Spanish voiced obstruent allophony: Costa Rican versus Iberian Spanish. *Phonetica*, 69(3), 149-179. https://doi.org/10.1159/000345199

Chavarría Aguilar, Óscar Luis (1951). The phonemes of Costa Rican Spanish. *Language*, 27(3), 248-253. https://doi.org/10.2307/409754

Daniloff, R. G., & Hammarberg, R. E. (1973). On defining coarticulation. *Journal of Phonetics*, 1(3),239-248. https://doi.org/10.1016/S0095- 4470(19)31388-9

Dearstyne, Matt (2021). Rhotic variation in Costa Rican Spanish: a preliminary acoustic analysis. *Cadernos de Linguística*, 2(1), e294-e294. https://doi.org/10.25189/2675-4916.2021.v2.n1.id294

Figueroa Candia, Mauricio & Soto-Barba, Jaime & Raguileo Ñanculeo, Marco. (2010). Los alófonos del grupo consonántico/tr/en el castellano de Chile. *Onomázein*, (22), 11-42. https://doi.org/10.7764/onomazein.22.01

Hall, Nancy. (2006). Cross-linguistic patterns of vowel intrusion. *Phonology*, 23(3), 387- 429. https://doi.org/10.1017/S0952675706000996

Henriksen, Nicholas. (2015). Acoustic analysis of the rhotic contrast in Chicagoland Spanish: An inter-generational study. *Linguistic Approaches to Bilingualism*, 5(3), 285- 321. https://doi.org/10.1075/lab.5.3.01hen

Hualde, José Ignacio. (2014). *Los sonidos del español: Spanish Language edition*. Cambridge University Press. https://doi.org/10.1017/CBO9780511719943

Kim, Ji Young & Repiso Puigdelliura, Gemma. (2020). Deconstructing heritage language dominance: Effects of proficiency, use, and input on heritage speakers' production of the Spanish alveolar tap. *Phonetica*, 77(1),55-80. https://doi.org/10.1159/000501188

Kingston, John. (2008). Lenition. In L. Colantoni, & J. Steele (Eds.), *Proceedings of the 3rd Conference on Laboratory Approaches to Spanish Phonology* (pp.1-31). Somerville: Cascadilla.

Kirchner, Robert (2013). *An effort based approach to consonant lenition*. Routledge. https://doi.org/10.4324/9781315023731

Lenth, R.V. (2021) Emmeans: Estimated Marginal Means, Aka Least-Squares Means. https://cran.r-project.org/package=emmeans

Lipski, John M. (2012). Geographical and social varieties of Spanish: An overview. *The handbook of Hispanic linguistics*, 1-26. https://doi.org/10.1002/9781118228098.ch1

Massone, María Ignacia (1988). Estudio acústico y perceptivo de las consonantes nasales y líquidas del español. *Estudios de fonética experimental*, 13-34. https://raco.cat/index.php/EFE/art icle/view/144221.

Odden, David. (2013). *Introducing phonology*. Cambridge University Press. https://doi.org/10.1017/CBO9781139381727

Quesada Pacheco, Miguel Ángel & Vargas Vargas, Luis (2010). Rasgos fonéticos del español de Costa Rica. In: Quesada Pacheco, M. A. (Ed.), *El español hablado en América Central*, Madrid: Editorial Iberoamericana, p.155-175. https://doi.org/10.31819/9783865278708-007

Quesada Pacheco, Miguel Ángel (1992). Pequeño atlas lingüístico de Costa Rica. *Revista de Filología y Lingüística de la Universidad de Costa Rica*, 18(2), 85-189. https://doi.org/10.15517/rfl.v18i2.20395

Ramus, F., Nespor, M., & Mehler, J. (1999). Correlates of linguistic rhythm in the speech signal. *Cognition*, 73(3), 265-292. https://doi.org/10.1016/S0010-0277(00)00101-3

Salazar Rodó, Sergio (2022). *Rhotics in Costa Rican Spanish: An Acoustic Study*. https://purl.lib.fsu.edu/diginole/FSU_libsubv1_scholarship_submission_16506 5662 2_3f5de421

Saporta, Sol (1955). Frequency of consonant clusters. *Language*, 31(1), 25-30. https://doi.org/10.2307/410889

Ségéral, Philippe & Scheer, Tobias (2008). Positional factors in lenition and fortition. *Lenition and fortition*, 131-172. https://doi.org/10.1515/9783110211443.1.131

Schmeiser B. (2020). Prosodic and segmental effects on the durational variability of svarabhakti vowels in Spanish /CR/ clusters. In *Proceedings of the international conference on speech prosody* (pp. 16–20). https://www.isca-archive.org/speechprosody_2020/schmeiser20_speechprosody.pdf

Schmeiser, Benjamin (2009). Prosodic and segmental effects on vowel intrusion duration in Spanish/ɾC/clusters. *Phonetics and Phonology: Interactions and Interrelations*, 306, 181-202. https://doi.org/10.1075/cilt.306.09sch

Schmeiser, Benjamin (2006). On the durational variability of svarabhakti vowels in Spanish consonant clusters. [PhD Thesis]. University of California, Davis.

Szigetvári, Péter (2008). Two directions for lenition. Lenition and fortition, 561-592. https://doi.org/10.1515/9783110211443.3.561

Vásquez Carranza, Luz Marina. (2006). On the phonetic realization and distribution of Costa Rican rhotics. *Revista de filología y lingüística de la Universidad de Costa Rica*, 32(2), 291-309. https://doi.org/10.15517/rfl.v32i2.4299

Warner, Natasha & Tucker, Benjamin V. (2011). Phonetic variability of stops and flaps in spontaneous and careful speech. *The Journal of the Acoustical Society of America*, 130(3), 1606-1617. https://doi.org/10.1121/1.3621306