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# A Variationist Analysis of Second Language Spanish Trill Production

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**Abstract:** The current study examines the production of the Spanish trill by advanced second language (L2) learners using a variationist approach. Findings indicate that learners produced less multiple occlusion trills than native speakers and their variation was not constrained by the same factors as native speakers. Phonetic context conditioned the use of the multiple occlusion variant for native speakers, whereas frequency and speaker sex conditioned this variation for learners, and in the opposite direction of effect as expected from previous native speaker research. Nevertheless, the majority of tokens produced by learners were other variants also produced by native speakers, and when the variation between native and non-native variants was examined, learners' variation was conditioned not only by frequency, but also phonetic context. Some of the phonetic contexts in which learners produced non-native variants were comparable to those in which native speakers were least likely to produce the multiple occlusion trill, indicating that articulatory constraints governed variation in trill production similarly for both groups. Thus, although L2 learners do not exhibit native-like trill variation, they appear to be developing toward a more native-like norm. These insights provide support for adopting a multifaceted variationist approach to the study of L2 phonological variable structures.

**Keywords:** second language acquisition, tap, trill, variation, variationist

## 1 Introduction

Spanish has two rhotic phonemes, the tap /ɾ/ and trill /r/, which numerous studies have found to pose difficulties for English-speaking learners of Spanish (e.g., Face 2006; Major 1986; Olsen 2012; Reeder 1998; Rose 2010; Waltmunson 2005). These studies have concluded that second language (L2) learners are generally unable to produce the trill in a target-like manner, that is, with two or more occlusions; however, not as much attention has been paid to what other variants learners

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produce in addition to the voiced alveolar trill with multiple occlusions and what conditions this variation.

The realization of the trill is in fact quite variable in native speech, and previous research has found that both linguistic and extralinguistic factors condition the variants produced (e.g., Díaz-Campos 2008; Diez Canseco 1997; Widdison 1998). Given the variable nature of this segment in native production, it is possible that the variation exhibited by L2 learners is similarly governed by such factors. In this case, advanced L2 learners may be closer to approaching a native-like phonological grammar than previous research would suggest. Alternately, it is possible that learners' variable production does not mirror native speaker variation in the distribution of trill variants or the factors that constrain their use, but rather represents developmental interlanguage forms in learners' attempt to produce a voiced alveolar multiple occlusion trill.

By comparing native-speaker and L2 trill production, both examined through a variationist lens, this study investigates whether the presence of trill variation in advanced learners' speech is due to the acquisition of native-like patterns of variation, the employment of interlanguage forms, or a combination thereof.

## 2 Trill Production by Native Spanish Speakers

As Hualde (2005) explains, the Spanish rhotic sounds, the tap /ɾ/ and the trill /r/, create a phonemic contrast in intervocalic position, as in *pero* /pero/ 'but' and *perro* /pero/ 'dog.' Otherwise, these two sounds demonstrate a partially complementary distribution: the trill occurs in word-initial position and word-internally following a consonant in a previous syllable, while the tap appears in onset clusters and word-finally before a vowel. Two phonetic environments allow for variation between these two sounds – before a consonant within a word or word-finally before a pause or a consonant – although the tap is the most common realization in both of these cases. Regarding articulation, the tap is produced via a brief period of contact between the tip of the tongue and the alveolar ridge, whereas the trill involves two or more rapid contacts of the tongue tip against the alveolar ridge.

Although prescriptively the realizations and distributions of the two rhotics are straightforward, extensive research has revealed that natural speech rarely follows these precise patterns. The trill in particular is quite variable in its pronunciation, and often a voiced alveolar trill with multiple occlusions does not constitute the majority of tokens. For example, in a study of speakers from Caracas, Venezuela, Díaz-Campos (2008) found that the multiple occlusion trill accounted for only 36.2% of realizations, while the remaining tokens were approximant variants. Similarly, Henriksen and Willis (2010) reported that the canonical trill

was produced in only 29.8% of prescriptive contexts by speakers from Jerez, Spain. In contrast, a realization with one occlusion followed by frication, by an approximant, or by r-coloring constituted the largest portion of the tokens. Fricative, approximant, and tap variants were also attested by Bradley (2006) in the speech of a wide variety of Latin Americans – Bolivians, Colombians, Costa Ricans, Ecuadorians, Guatemalans, Hondurans, and Mexicans – who produced only 16% of their tokens as multiple occlusion trills. In the most extreme example, Willis (2007) found that a mere 4.2% of tokens in Cibaeño Dominican Spanish were produced as the canonical multiple occlusion variant; most tokens were prebreathy voiced variants with one or more occlusions. Even in a study on the Spanish of León and Ciudad Real, two Peninsular varieties that are typically regarded as conservative in their pronunciation, Henriksen (2014) reported that about a third of phonemic trills were not produced according to the prescriptive norm, but instead exhibited less than two occlusions.

Given the evidence that phonemic trills are frequently produced with one or zero occlusions, it stands to wonder whether the phonological contrast between the tap and trill is maintained by native speakers. Researchers that have addressed this question have reported that this contrast is indeed maintained (Bradley and Willis 2012; Henriksen and Willis 2010; Willis and Bradley 2008). This is not accomplished through the number of occlusions, necessarily, but instead via duration; speakers produce phonological trills as significantly longer than phonological taps. Thus, despite the extensive variation in how the trill phoneme is produced – variation which has been attested not only within dialects, but within the speech of individuals as well (Henriksen 2014; Henriksen and Willis 2010; Willis 2006, 2007) – speakers' pronunciation of this segment is not arbitrary. This is further illustrated by the multitude of studies that have discovered linguistic and extralinguistic factors conditioning trill variation.

Regarding the linguistic factors constraining trill variation, research has found that the phonetic context of the trill phoneme, both in terms of stress position and the nature of the surrounding segments, can affect pronunciation. The results on the effect of stress have been divided. In the syllable onset, Zahler and Daidone (2014), Lamy (2015), and Melero García (2015) found that stressed syllables favored the multiple occlusion variant, while conversely Henriksen and Willis (2010) and Henriksen (2014) noted that unstressed syllables favored more occlusions, and Lewis (2004) found no effect of stress. Studies have also reported mixed results for the effects of surrounding segments, perhaps at least in part because this has been operationalized in different ways. Lamy (2015) looked at place of articulation and found that preceding posterior sounds like /h/, /o/, and /u/ favored the multiple occlusion variant, while Díaz-Campos (2008) and Zahler and Daidone (2014) did not find a significant effect of place of articulation for the preceding or following

sound. Henriksen (2014) found that a preceding /u/ corresponded to a lower number of occlusions compared to /a/, /e/, and /o/, while the following vowel did not have a significant effect. In addition, Solé (2002) reported that the context [i]_[i] corresponded with shorter and fewer multiple occlusion trills compared to [a]_[a]. Despite this variation in results, one finding on which studies do agree is that a preceding /s/ disfavors the multiple occlusion variant compared to other consonants or a vowel (Bradley 2006; Diez Canseco 1997; Lewis 2004).

Several properties at the lexical level have also been shown to affect trill production, including the position of the phoneme within the word, as well as the word's number of syllables, grammatical category, corpus frequency, and number of phonological neighbors. Most studies have reported that /r/ has a higher rate of multiple occlusions or a longer duration in word-initial position (Díaz-Campos 2008; Diez Canseco 1997; Melero García 2015; Willis 2006, 2007), although other studies have found that it is word-internal position which favors multiple occlusions (Henriksen and Willis 2010; Lastra and Butragueño 2006). Zahler and Daidone (2014) described a nuanced difference by position: the multiple occlusion variant was favored in intervocalic position and word-initially after a consonant, whereas it was disfavored word-initially after a vowel or a pause. As for number of syllables, Díaz-Campos (2008) reported that words with four or more syllables favored the production of the prescriptive variant, whereas words with one to three syllables disfavored it. Lamy (2015), on the other hand, found the opposite effect. Díaz-Campos (2008) also found that grammatical category affected the production of the trill, with adjectives and verbs favoring a variant with multiple occlusions and nouns and adverbs disfavoring this realization. However, in the same study, Díaz-Campos suggested that the effects of position of the phoneme within the word, number of syllables, and grammatical category may all be related to the frequency and usage of individual lexical items. Evidence for this conclusion can be found in the results of Zahler and Daidone (2014), who showed that corpus frequency was significantly correlated with all three of these factors and that higher frequency correlated with lesser production of the multiple occlusion variant. This effect of frequency was also obtained by Lamy (2015). Conversely, Melero García (2018) reported the opposite effect of frequency; in his study, higher frequency favored production of the canonical variant. Regarding a different lexical property, Zahler and Daidone (2014) reported that words with a higher number of phonological neighbors (i.e., lexical items that differ from a word only in the addition, substitution, or deletion of a single phoneme) were more likely to be produced with a multiple occlusion variant. Melero García (2018) also found an effect of phonological neighborhood density: the more high frequency phonological neighbors the word had, the longer speakers produced the duration of /r/.

Extralinguistic factors that have been shown to influence trill production include the type of elicitation task as well as speakers' age, sex, beliefs, social class, social networks, and place of residence. Results differ somewhat on the effect of age. Some studies have found that older speakers favor the multiple occlusion variant (Díaz-Campos 2008; Melero García 2015; Zahler and Daidone 2014). Other studies have found that older speakers are more likely to prefer a noncanonical variant than younger speakers (Henriksen and Willis 2010; Lastra and Butragueño 2006). Lastly, Lamy (2015) found that older and younger speakers pattern together in producing more noncanonical variants while speakers of working age favor the multiple occlusion variant. Regarding speaker sex, studies have typically stated that women produce more of the multiple occlusion variant (Bradley and Willis 2012; Díaz-Campos 2008; Henriksen 2014; Henriksen and Willis 2010; Melero García 2015). However, this pattern is not always the case (Diez Canseco 1997; Lamy 2015; Melero García 2018), especially when a different variant is considered a prestige form for women (Lastra and Butragueño 2006), or a marker of traditional views of gender roles (Rissel 1989). Diez Canseco (1997) also found a role for speakers' beliefs, such that differing attitudes toward Peruvian Spanish and Quechua were mirrored by somewhat different rates of /r/ variants. Middle class speakers have been documented as using the standard multiple occlusion variant more often than lower class speakers (Díaz-Campos 2008; Diez Canseco 1997; Lamy 2015; Melero García 2018), and urban speakers have been shown to use the multiple occlusion variant slightly more often than rural speakers (Diez Canseco 1997). Diez Canseco (1997) also found that the characteristics of speakers' social networks played a role in their /r/ pronunciation, as did the type of elicitation task, with word-naming producing the highest rate of multiple occlusion trills.

By treating the trill as a variable structure in the sociolinguistic sense, researchers have gained a rich picture of the many different phonetic realizations that native speakers produce in addition to the canonical voiced alveolar trill with two or three occlusions. They have discovered that despite the chaotic appearance of trill production, native speakers preserve the phonemic distinction between the tap and the trill, and that both linguistic and extralinguistic factors govern the use of different variants, sometimes differing based on the dialect under investigation. In comparison, as a field we know little about the distribution of variants that L2 learners of Spanish use for the trill phoneme, and almost nothing about what factors condition this variation for them.

## 3 Trill Production by Second Language Learners

American and British English have a single rhotic phoneme which is realized most often as a voiced alveolar approximant [ɹ] and thus is different from either of the

Spanish rhotics (Ladefoged and Johnson 2010; Roach 2004). Previous research on the acquisition of the Spanish trill by English-speaking learners has found that accuracy in trill realization, often defined as production of the multiple occlusion variant, is generally very low for beginner learners and increases with proficiency level, but even advanced speakers often fail to produce a trill with multiple occlusions (Bongiovanni et al. 2015; Face 2006, 2018; Major 1986; Olsen 2012, 2016; Reeder 1998; Rose 2010; Waltmunson 2005). For example, in Reeder's (1998) study on the production of the trill phoneme in intervocalic position, first semester students produced a multiple occlusion variant in only 7% of target contexts, third semester students in 13%, and upper division undergraduate and graduate students in 37%. Only faculty members produced /r/ with multiple occlusions in the majority of contexts, at a rate of 83%. These findings are strengthened by the results of Face (2006), in which fourth semester students produced the multiple occlusion variant in merely 5.1% of the target intervocalic contexts, and advanced majors or minors in 26.6%. The advanced learners studied by Rose (2010) tended to produce more multiple occlusion variants than those whose production was analyzed in previous literature, with 67% realization by first year doctoral students, but beginner learners still showed a similar low rate of production of this canonical variant (5% by third semester students, 27% by fifth semester students, and 2% by eighth semester students). In place of the canonical variant, studies have reported that learners typically use other variants, which may be either non-native or native-like. Face (2006) found that even advanced majors or minors most often realized Spanish /r/ in a non-native manner as an English-like voiced alveolar approximant, but learners also produced taps, approximants, and assibilated variants, which have been attested in native speech. Waltmunson (2005), Rose (2010), Face (2018), and Bongiovanni et al. (2015) similarly reported that learners realized /r/ with non-native variants such as an English-like alveolar approximant, as well as producing native-like variants like a tap, a tap with frication, and assibilation.

These results illustrate that the multiple occlusion variant is not the most common form produced by L2 learners until advanced levels of proficiency, and even at this level, learners often produce other variants, which may or may not be similar to what native speakers produce. Nevertheless, Amengual (2016) found that L2 speakers maintained a tap-trill distinction through duration, such that phonological trills were longer even if they did not exhibit two or more occlusions, a finding which mirrors the research on native speaker varieties. Furthermore, Face (2018) found that three of the eight English-speaking immigrants to Spain that he recorded had a rate of multiple occlusion production that was within the range of native speakers, although only one speaker had a native-like rate of production in addition to consistently native-like duration for all tokens of /r/. Rose (2010) reported that three of the five advanced L2 participants her in study used only trill

variants and tap variants that the native speaker participants produced, such as producing /ɾ/ as a tap plus frication and /ɾ/ as a lenited tap, and thus they differentiated the phonological tap and trill contexts with the same types of realizations as native speakers. These results suggest that learners may be capable of acquiring native-like trill variation.

## 4 Variationist Approaches to L2 Production

Variationist approaches allow researchers to probabilistically model under which conditions a speaker is likely to produce a certain form. This approach, which originated with quantitative sociolinguistics, has more recently been applied to examine variation in the forms produced by L2 learners (Geeslin and Long 2014). This includes both Type I variation, or the variation between native and non-native forms, as well as Type II variation, or the variation between native forms (e.g., Mougeon et al. 2004; Rehner 2002).

The variationist approach was first applied in L2 acquisition research to study development toward a native norm (see Bayley 2005; Regan 2013). In these Type I studies, researchers examined variation in learners' interlanguage, or L2 system, in order to determine what conditions were favorable for accurate production. Given that learners' interlanguage often contains forms that are not found in the first or second language (Selinker 2014), this research takes into consideration all forms that are used in the target context. In addition, from the earliest variationist studies on L2 phonological acquisition, researchers have examined the impact of both linguistic factors, such as phonological environment, and extralinguistic factors, such as task type. For example, Dickerson (1975) examined the acquisition of English /z/ by Japanese-speaking learners. She found that the accuracy of /z/ pronunciation depended on the following sound, the type of task, and the time of testing. Most relevant to the current study, a pair of studies have looked at overall rhotic variation from a Type I perspective, investigating what factors lead to native-like production of Spanish tap and trill. These studies examined factors affecting the production of Spanish rhotics as a whole, combining both phonological tap and trill contexts in the analysis. Hurtado and Estrada (2010), who defined accurate production as all variants previously attested in native speaker production for the tap and trill, found that phonological context, position within the word, the type of discourse (i.e., task type), the time of recording (before or after instruction), the focus of the exercise, and the level of classes taken abroad all impacted learners' production. Similarly, Weech (2009) defined accurate production as canonical realizations of the tap and trill along with any dialectal variants attested in dialects with which a learner had contact. He reported that Spanish instruction

before going abroad and phonetic context of the rhotic conditioned whether learners used accurate pronunciation. Across both studies, a syllable-initial rhotic was more likely to be accurate than a word-initial rhotic, and more formal instruction corresponded to more native-like production.

Variationist work has also focused on Type II variation and the L2 acquisition of sociophonetic variation between native forms. These studies have examined phenomenon such as /l/-deletion, schwa deletion, and liaison in French (French and Beaulieu 2016; Howard 2006; Howard et al. 2006; Mougeon et al. 2004; Thomas 2004; Uritescu et al. 2004) and variable (ing) realization in English (Adamson and Regan 1991; Drummond 2012; Major 2004). For example, Uritescu et al. (2004) found that both linguistic and extralinguistic factors influenced schwa deletion for L2 learners of French. In their study, English-speaking students in a French immersion program in Canada deleted schwa less frequently than native speakers and were not sensitive to topic formality as a factor. However, they were influenced by phonetic context in the same way as native speakers. Additionally, those students who had more contact with native speakers had more native-like rates of schwa deletion. Thus, similar to variationist L2 research on morphology and syntax, these types of studies indicate that L2 phonological variation is systematic, often governed by many of the same factors that govern native speaker variation, and more native-like with increased proficiency or contact with the target language.

In contrast to French and English, research on the L2 acquisition of Spanish sociophonetic variables is largely non-existent. As Geeslin (2011) showed in her overview article on the acquisition of variation by L2 learners of Spanish, there is extensive research on the L2 use of variable morphosyntactic structures, such as the copulas *ser* and *estar*, null subjects, subjunctive mood, and past and future expression, but little research has been devoted to Spanish phonological variation. Furthermore, those studies that do investigate variable sounds focus almost exclusively on the acquisition of geographically-indexed features like the use of /θ/ or /s/-weakening, which generally have very low rates of production by learners (e.g., Geeslin and Gudmestad 2008). Only recently has the variationist approach begun to be extended to Spanish phonological variables, notably in the work of Solon et al. (2018) on /d/ lenition and deletion. Consequently, additional variationist research on the L2 acquisition of variable phonological structures in Spanish is warranted to provide a more detailed picture of learners' L2 phonological systems.

Examining L2 Spanish trill variation represents a case that does not fit neatly into studies of either Type I or Type II variation. Studies of Type I variation have investigated development toward a native-like norm, defined as categorical use of the target form. Given the variability in trill production by native speakers, there is not one single target form that represents accurate production. At the same time,

studies of Type II variation have examined learners' use of phonological structures that do not pose significant difficulty for learners, particularly at advanced levels. For example, English speakers are unlikely to have trouble producing the presence or absence of /l/ or schwa. In contrast, the trill represents a segment that is articulatorily difficult and thus more likely to exhibit interlanguage forms, rather than only native forms, even for advanced learners. For these reasons, an investigation of L2 Spanish trill variation would benefit from considering not only the factors that condition learners' production of the canonical multiple occlusion variant versus all other variants (both native and non-native), but also the factors that condition the use of native versus non-native forms.

# 5 The Current Study

While trill variation has been extensively documented in native speaker varieties, research on trill production by L2 learners has typically focused on accuracy rates for the canonical multiple occlusion variant. Examining L2 trill production from a variationist perspective offers an opportunity to determine if advanced learners' variation mirrors native-like production, in terms of both frequency of different variants and the linguistic and extralinguistic factors that constrain their production. Furthermore, because learners have been found to produce a range of native-like variants as well as non-native forms, a variationist approach can be applied to examine the factors that predict the production of a canonical multiple occlusion trill, in parallel to studies on native speakers' trill variation, as well as what factors condition the production of native-like variants as opposed to non-native forms. This investigation is guided by the following research questions:

1. What is the rate of production of different trill variants for L2 learners and native Spanish speakers?
2. Which factors condition L2 learners' and native speakers' trill variation?
3. Do L2 learners and native speakers maintain a tap-trill contrast?

# 6 Method

## 6.1 Corpora

The data for this study came from the Spanish Learner Language Oral Corpora (SPLLOC) (Mitchell et al. 2008). The SPLLOC consists of two corpora, SPLLOC 1 and SPLLOC 2, that contain oral productions from British English-speaking learners of Spanish and native Spanish speakers from Spain completing various tasks, such as

narrating a story, describing photos, completing a discussion in pairs, and participating in an interview. In the corpora, there are three proficiency levels labeled as 'beginners', 'intermediate' and 'advanced'. The productions of six male and six female learners at the advanced proficiency level were analyzed. The highest proficiency level was chosen because previous research has shown that more advanced learners of Spanish are more likely to produce a canonical multiple occlusion trill than learners at lower levels of proficiency. Additionally, learners' ability to vary in the L2 in nativelike ways is acquired late and increases as proficiency increases (see Geeslin (2011) for an overview). These specific advanced speakers had learned Spanish in foreign language classrooms in the UK, and had also spent a year abroad in Spain. Thus, their target variety of the language was presumably Peninsular Spanish. They had approximately 895 h of classroom instruction and an estimated Spanish Common European Framework of Reference for Languages (CEFR) level of C1-C2. Data from Peninsular Spanish native speakers who were age-matched to the L2 learners were also extracted from the corpora. Overall, the participants ranged from 17–22 years old. Due to various limitations of the online corpora (missing, mislabeled, or corrupt sound files) and variation in the number of words containing the trill across individual speakers, the native speaker control group consisted of many more speakers (6 males and 12 females) in order to achieve a comparable number of tokens to those extracted from the L2 learners' productions.

## 6.2 Coding

The dependent variable in the current study was the production of the trill phoneme. All analyzable tokens of the trill, /r/, were extracted for all sound files available for each speaker. That is, all word-initial rhotics, word-internal rhotics following a consonant, and intervocalic rhotics with orthographic <rr> were considered. Tokens occurring during excessive background noise or overlapping speech were discarded, as was one of the learner tokens for which the pronunciation could not be determined due to unclear spectrographic and acoustic evidence. This process resulted in 376 trill tokens for native speakers, with an average of 21 tokens per speaker (range 5–32, SD = 7.5). The learners produced 464 tokens of the trill phoneme, with an average of 39 tokens per speaker (range 12–68, SD = 14.9). In order to answer research question 1, tokens were acoustically analyzed with Praat (Boersma and Weenink 2019) and classified as one of the eight categories outlined below.

1. voiced alveolar multiple occlusion variant with two or more closures (i.e., canonical pronunciation)
2. voiced alveolar tap (i.e., one occlusion)

3. a voiced alveolar tap with another element such as frication, a partial occlusion, or a native-like approximant (i.e., tap+)
4. approximant with stable F3 and without audible r-coloring (i.e., native-like approximant)
5. assibilated rhotic (i.e., frication)
6. elision
7. approximant with lowered F3 and audible r-coloring (i.e., English-like approximant)
8. rhotic with an epenthetic vowel inserted beforehand

These categories were created based on the evidence found in the data. Categories one through six were found in the native Spanish speaker data, while categories seven and eight were not and, thus, were considered non-native. The first category is the multiple occlusion variant, which had to have two or more clear full occlusions to be categorized as such. The second category, a voiced alveolar tap, had one clear occlusion without visible formant structure. The category of tap plus, category 3, was created for variants that had a voiced alveolar tap with another element, such as r-coloring or frication as in Figure 4. Category 4, a native-like approximant, had to have a stable F3 and no audible r-coloring. An assibilated rhotic, category 5, had to display frication throughout, while tokens classified as elision, category 6, had no presence of a rhotic, audibly or visibly in the spectrograph. The first non-native category, category 7, was used for all occurrences of English-like approximants that had a clearly lowered F3 and audible r-coloring. Lastly, the second non-native category, category 8, was used for cases where the

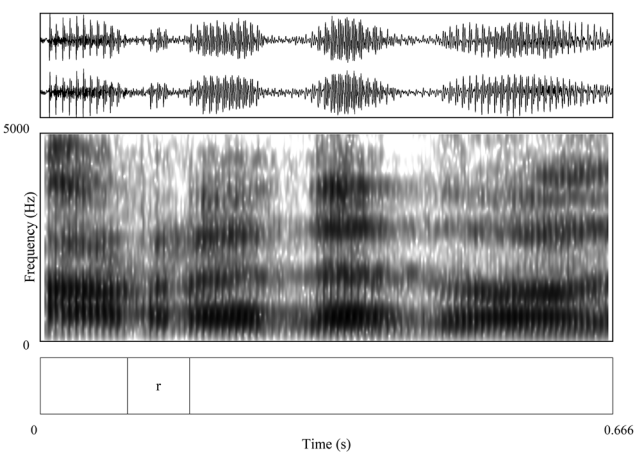


**Figure 1:** Multiple occlusion variant with two occlusions. *Alrededor* (L84.P).

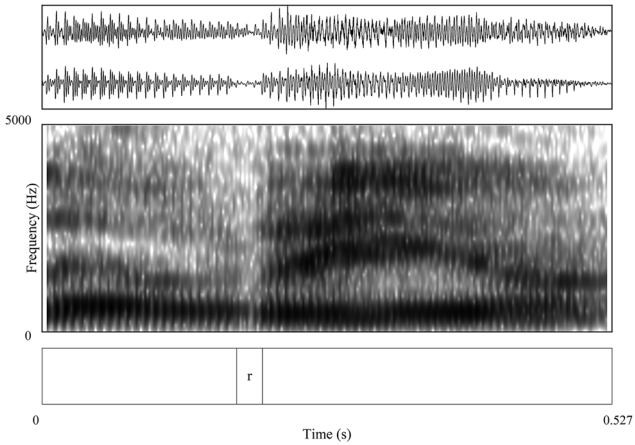


**Figure 2:** Voiced alveolar tap with one occlusion. *Un río* (L84.L).

rhotic was preceded by an epenthetic vowel, as indicated audibly and by periodicity in the waveform and formant structure in the spectrograph. The vocalic element ranged from schwa to a copy of the vowel following /r/, and the rhotic element was a tap, a tap followed by r-coloring or frication, or a native-like approximant. Despite the generally native-like nature of the rhotic, this variant was considered to be non-native because of the epenthetic vowel beforehand, which none of the native-speaker tokens exhibited. Both researchers analyzed all trill tokens together and agreed on the final coding for each one. Examples of variants 1–8 produced by learners are displayed in Figures 1–8.

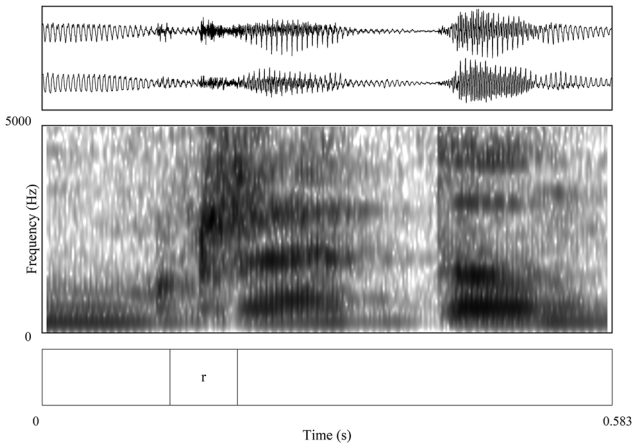


**Figure 3:** Tap with frication. *Raton- from ratoncito* (L70.C).

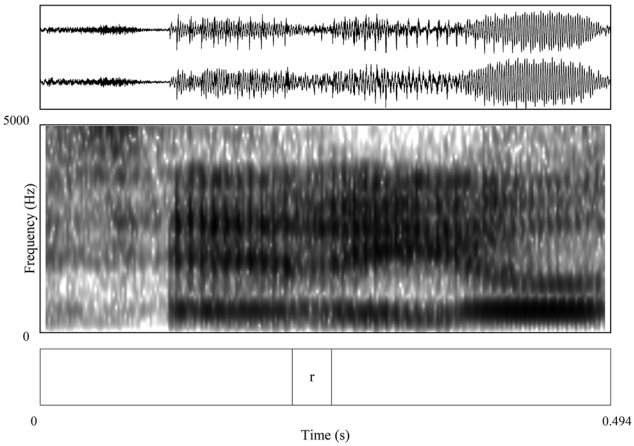


**Figure 4:** Native approximant. *Se rió* (L73b.H).

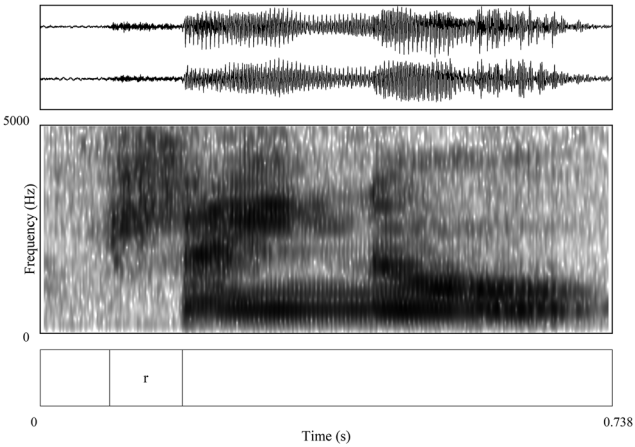


**Figure 5:** Assibilated rhotic. *Reino* (L70.L).

In order to answer research question 2, each trill token was coded according to independent variables evidenced in previous research as affecting native speaker and learner trill variation. These included the manner of articulation of the preceding segment, place of articulation of the following vowel, syllable stress, position within the word, sex of the speaker, log frequency of the word, and the number of phonological neighbors. For preceding segment manner, we divided the category into obstruents, sonorant consonants, and high, mid, and low vowels to determine whether degree of constriction of the surrounding phonetic environment affected

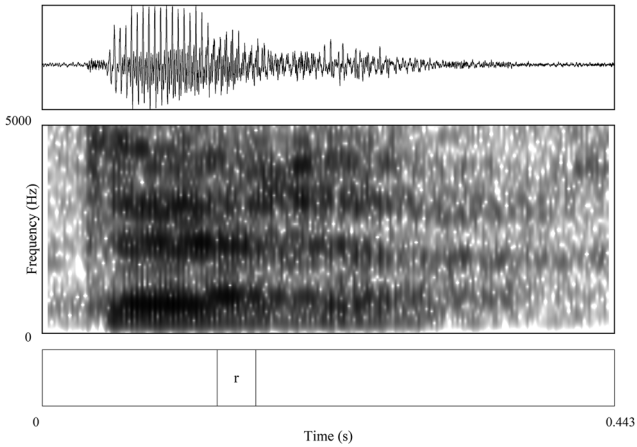


**Figure 6:** Elision. –*terra* from *Inglaterra* (L71.P).

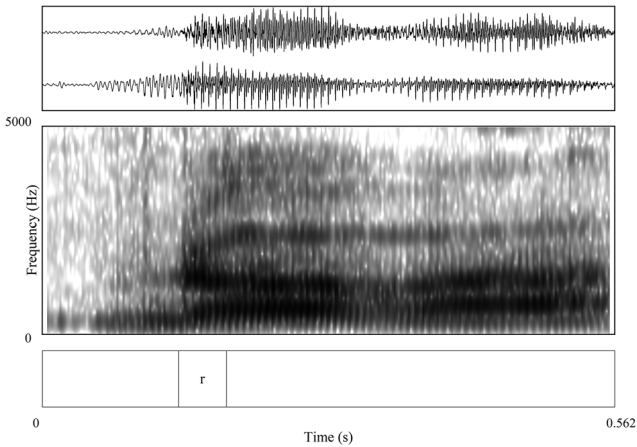


**Figure 7:** English-like approximant. *Roba* (L71.P).

trill production. This was done due to prior research indicating that more constricted vocalic environments (e.g., /i_i/) and a preceding /s/ disfavor the multiple occlusion variant compared to less constricted vocalic environments (e.g., /a_a/) (Bradley 2006; Diez Canseco 1997; Lewis 2004; Solé 2002). Additionally, preliminary analyses indicated that preceding vowels patterned similarly by height. For following vowel position, we grouped front, central, and back vowels together due to preliminary analyses that found that these vowels patterned similarly based on vowel frontness/backness. Log frequency values and the number of higher frequency phonological

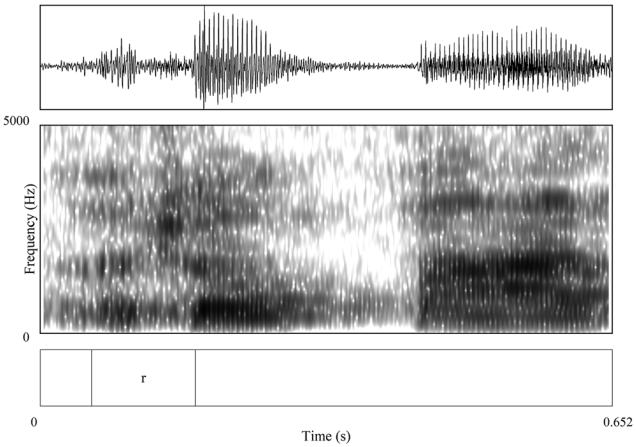


**Figure 8:** Rhotic with preceding epenthetic vowel. *Ropa* (L73.P).

neighbors were obtained from EsPal (Duchon et al. 2013), a resource that provides the properties of Spanish words, such as frequency measures, phonological neighborhoods, orthographic neighborhoods, and orthographic and phonological structure. These word properties were determined based on a lexical corpus created from written web resources and movie subtitles. We chose log frequency as the frequency measure for two reasons. First, although Zahler and Daidone (2014) found that their corpus-specific frequency more strongly correlated with production of the multiple occlusion variant in the speech of native speakers of Málaga, Spain, their corpus was composed of sociolinguistic interviews on a range of topics, and thus included a variety of words. The corpus used for this study was comprised of a number of tasks that elicited particular vocabulary items. Several of these tasks were narrations of pictures and silent films and included a clitic production task that involved the repetition of specific sentences. Only two tasks involved spontaneous speech on a variety of topics, the discussion task and interview. Because of this, the corpus used in the current study demonstrates less lexical variety. Corpus frequency in the current study, thus, interacted with a number of the linguistic factors since several words were repeated frequently. Additionally, in several instances the corpus-specific frequency of a word diverged greatly from its overall frequency, as determined by its frequency in EsPal, a much larger corpus with language samples from a variety of contexts. For these reasons, a frequency measure from a broader, more varied corpus (EsPal) was obtained to avoid the interactions mentioned above and to provide a more reliable measure of frequency. Secondly, log frequency as opposed to raw frequency was specifically chosen to lessen the disparity between low frequency tokens, of which there are many more, and high frequency tokens, of

which there are fewer (Gries 2009; Raymond and Brown 2012). We chose number of higher frequency phonological neighbors as the measure for phonological neighborhood density as opposed to the total number of phonological neighbors because learners were more likely to have higher frequency phonological neighbors in their lexicon, as opposed to all of a word's phonological neighbors. The specific categories for each factor are outlined in Table 1.

Lastly, in order to determine if speakers maintained a duration difference between one-occlusion trills and phonological taps (research question 3), tokens of word-internal intervocalic /ɾ/, represented orthographically as <r>, were also extracted for each speaker, up through each speaker's 20th unique word. The tokens extracted were evenly divided between all of a speaker's tasks as much as possible, and any words that were repeated in the sound files were included until 20 different words were reached. For example, a total of 37 tokens were extracted for Participant 73 because frequent words such as *para* 'for' and *pero* 'but' were repeated by the speaker and were included in the analysis. This was done in order to strike a balance between sampling the tap in a variety of words and reflecting the fact that the tap appeared most often in certain high frequency words. This process resulted in 386 tap tokens for the native speakers and 357 tap tokens for the learners.

**Table 1:** Independent variables.

| Independent variable | Categories |
|---|---|
| Preceding segment manner | High vowel |
| | Mid vowel |
| | Low vowel |
| | Obstruent |
| | Sonorant consonant |
| | Pause |
| Following vowel position | Front vowel |
| | Central vowel |
| | Back vowel |
| Syllable stress | Stressed |
| | Unstressed |
| Position in word | Intervocalic |
| | Word-internal, after /s/, /n/, or /l/ |
| | Word-initial, after a vowel |
| | Word-initial, after a consonant |
| | Word-initial, after a pause |
| Speaker sex | Female |
| | Male |
| Log frequency of the word | *Continuous* (range = 0–2.654051) |
| Number of higher frequency phonological neighbors | *Continuous* (range = 0–13) |

## 6.3 Analysis

First, the distribution of the different variants produced for the trill phoneme was calculated within the native speaker data and within the learner data in order to answer research question 1. Subsequently, a series of fixed-effects logistic regression analyses were performed using Rbrul (Johnson 2009) in order to ascertain the effect of the independent variables on trill variation (research question 2). In each analysis, the dependent variable, trill variation, was binary; however, the categories of the dependent variable were defined differently depending on the particular analysis. First, one regression analysis was performed on the native speaker data, in which the dependent variable was categorized as either the multiple occlusion variant (two or more occlusions; category 1 in Section 6.2) or all other variants (categories 2–6). On the other hand, for the learner data, two separate analyses were run in which the dependent variable was defined distinctly. In the first analysis, the dependent variable was identical to that of the native speaker analysis: use of the multiple occlusion variant was compared to that of all other variants, although in this case the "all other variants" category included both native non-canonical sounds (categories 2–6) and non-native sounds (categories 7 and 8). In the second learner regression analysis, the dependent variable was grouped into native-like variants (categories 1–6 in Section 6.2) or non-native variants (categories 7 and 8).

Not all the independent variables originally coded were included in the final regression analyses. As described previously, due to the nature of the tasks, which elicited particular words, the data for this study come from a limited set of lexical items that were repeated frequently. In the native speaker data, there were 162 different surface forms, while in the learner data, 144 different surface forms were analyzed. If nouns marked differently for plurality and gender as well as the different verbal conjugations were grouped into lemmas, it is quite likely that the number of different lexical items would be much further reduced. Consequently, several of the independent variables interacted. First, position in word interacted with preceding segment manner and following vowel position for both the native speakers' and the learners' data. We opted to include a measure of phonetic context over position in word since phonetic context is more theoretically motivated given that native trill variation is believed to occur in part due to the articulatory difficulty in producing the multiple occlusion variant in certain phonetic environments (e.g., Solé 2002). Additionally, previous research for word position has been inconsistent (Díaz-Campos 2008; Diez Canseco 1997; Henriksen and Willis 2010; Lastra and Butragueño 2006; Melero García 2015; Willis 2006, 2007; Zahler and Daidone 2014). Secondly, preceding segment manner, following vowel position, and stress interacted for both analyses of the learners' data, and preceding segment manner also interacted with frequency. This interaction likely arose for the learners but not the native speakers

due to the specific words each group used. For example, the learners used the word *Inglaterra* 'England' frequently when talking about themselves; the native speakers, however, rarely used this word. We opted to retain following vowel position instead of preceding segment manner or stress since unlike preceding segment manner, following vowel position could be included in both learner regressions together with frequency, and unlike stress it exhibited substantial variation in the amount of variant use between categories. However, in order to compare with the native speaker analysis as much as possible, despite interactions, we also ran additional statistical analyses for learners with preceding segment manner replacing following vowel position, and with stress replacing following vowel position, but otherwise keeping the same independent variables. When reporting the distribution of the variants according to the categories of these two factors, we include the factor weights from their respective regression analyses.

It is also important to highlight that we ran a fixed-effects model without including participant as a random effect, rather than a mixed-effects regression analysis with participant as a random effect, since participants tended to use different sets of lexical items in the more open-ended tasks. Therefore, due to the specific words they produced, some participants' data contained /r/ tokens only in certain phonetic contexts. Because of this, participant was not included as a random effect. Consequently, the final independent variables included in the regression analysis for native speakers were log frequency, number of higher frequency phonological neighbors, preceding segment manner, following vowel position, stress, and speaker sex. For the learners, preceding segment manner and stress were not included in either analysis due to the aforementioned interactions. Thus, the regression analyses for learners included log frequency, number of higher frequency phonological neighbors, following vowel position, and speaker sex. Additionally, the distribution of variants according to preceding segment and stress for the learners will be provided in the results section, as well as the distribution according to word position for both participant groups. The independent variables included in each analysis are presented in Table 2.

Lastly, we conducted two independent *t*-tests, one each for the native speakers and learners, comparing the duration of taps produced in the phonological tap context and taps produced in the phonological trill context. This analysis was performed to answer research question 3.

# 7 Results

In the following sections, the results for the native speakers are presented first, followed by the findings for the L2 learners of Spanish. In the native speaker

**Table 2:** Variables for each regression analysis.

| Analysis | Dependent variable | Independent variables |
|---|---|---|
| Native speaker analysis | Multiple occlusion variant (category 1) versus all other productions (categories 2–6) | Log frequency<br>Number of higher frequency phonological neighbors<br>Preceding segment manner<br>Following vowel position<br>Stress<br>Speaker sex |
| L2 learner analysis 1 | Multiple occlusion variant (category 1) versus all other productions (categories 2–8) | Log frequency<br>Number of higher frequency phonological neighbors<br>Following vowel position<br>Speaker sex |
| L2 learner analysis 2 | Native-like variants (categories 1–6) versus non-native variants (categories 7–8) | Log frequency<br>Number of higher frequency phonological neighbors<br>Following vowel position<br>Speaker sex |

section, the rate of production of different variants in the trill phonological context is presented, followed by the regression analysis. Subsequently, the distribution of the trill variants for the factors not included in the regression analysis is provided, followed by a *t*-test comparing the duration of tap variants found in trill contexts to that of tap variants found in tap contexts. For the learners, the rate of production of different variants in the trill phonological context is given first, followed by the regression analysis examining the use of the canonical multiple occlusion variant, and then the distribution of trill variants according to the factors not included in this regression. Next, the native-like variant regression analysis is presented, as well as the distribution of native-like variants among factors not included in the regression analysis. Lastly, a *t*-test comparison of tap variant duration in trill contexts to tap variant duration in tap contexts is provided.

## 7.1 Native Speakers

In Figure 9, the overall distribution of trill variants in the trill context produced in native speaker speech is presented. The canonical multiple occlusion variant was the most common articulation for the trill phoneme, comprising 35.1% of the data. Although the overall rate was 35.1%, native speakers demonstrated individual

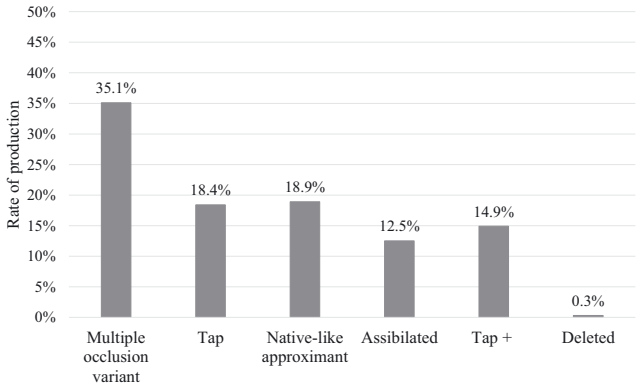


**Figure 9:** Distribution of trill variants in native speaker Spanish.

variation (range = 0.0–75.0%, SD = 24.4). Native speakers also produced a tap variant in 18.4% of the data and a native-like approximant in 18.9% of cases. Assibilated variants (12.5%) and tap+variants (14.9%) were likewise used relatively often by speakers, while the remaining variant, deletion, occurred infrequently at 0.3%.

In Table 3, the fixed-effects regression analysis for native speaker trill production is presented. The dependent variable was categorized as one of two possibilities: the canonical multiple occlusion variant or other variants produced by native speakers. Thirty-seven tokens from three native speakers (one female, two males) were excluded due to categorical non-use of the trill. Additionally, two tokens of monosyllabic words were excluded since they could not be coded according to stress, and six tokens of preceding pauses for preceding segment manner were excluded due to small token counts across cells. Consequently, the final token count included in the regression analysis was 331, with 45 tokens excluded. In the table, factors with a *p*-value of less than 0.05 are statistically significant. For the categories of each discrete factor, a factor weight is provided. Factors weights above 0.50 indicate that the category favors production of the multiple occlusion variant, while factor weights below 0.50 indicate that the category disfavors the multiple occlusion variant. For continuous factors, which in the current study are log frequency and number of phonological neighbors, log odds are provided. Positive log odds indicate a positive correlation between the continuous factor and use of the multiple occlusion variant. Negative log odds designate the inverse. Brackets appear around factor weights and log odds for variables not found to be significant predictors.

In the regression analysis, only preceding segment manner had a *p*-value of less than 0.05, and thus was the only statistically significant variable. The use of

**Table 3:** Factors affecting production of the multiple occlusion variant in native speaker speech.

| Factor | *N* | % multiple occlusion variant | Factor weight/log odds |
|---|---|---|---|
| **Preceding segment manner (*p* = 0.0427)** | | | |
| Low vowel | 78 | 43.6% | 0.63 |
| Sonorant consonant | 77 | 42.9% | 0.63 |
| Mid vowel | 132 | 40.2% | 0.60 |
| High vowel | 24 | 29.2% | 0.48 |
| Obstruent | 20 | 10.0% | 0.21 |
| **Following vowel position (*p* = 0.440)** | | | |
| Central vowel | 56 | 48.2% | [0.57] |
| Front vowel | 215 | 38.1% | [0.48] |
| Back vowel | 60 | 33.3% | [0.45] |
| **Syllable stress (*p* = 0.661)** | | | |
| Stressed | 116 | 40.5% | [0.51] |
| Unstressed | 215 | 38.1% | [0.49] |
| **Speaker sex (*p* = 0.579)** | | | |
| Female | 241 | 39.8% | [0.52] |
| Male | 90 | 36.7% | [0.48] |
| **Log frequency (*p* = 0.906)** | | | [0.020] |
| **Number of higher frequency phonological neighbors (*p* = 0.978)** | | | [0.002] |

the multiple occlusion variant was favored when the preceding segment was a low vowel, sonorant consonant, or mid vowel. The multiple occlusion variant was disfavored when the preceding segment was a high vowel and was highly disfavored by a preceding obstruent. Following segment manner, syllable stress, speaker sex, log frequency, and number of higher frequency phonological neighbors did not constrain this variation.

Because position in word could not be included in the regression, the distribution of the multiple occlusion variant according to the categories of this variable is presented in Table 4.

**Table 4:** Distribution of the multiple occlusion variant.

| Factor | *N* | % multiple occlusion variant |
|---|---|---|
| **Position in word** | | |
| Word-internal, after /s/, /n/, or /l/ | 7 | 57.1% |
| Word-internal, intervocalic | 81 | 44.4% |
| Word-initial, after a vowel | 152 | 38.2% |
| Word-initial, after a consonant | 91 | 34.1% |

**Table 5:** Duration of taps produced in trill contexts and in tap contexts by native speakers.

| | Tap in trill context | Tap in tap context |
|---|---|---|
| Mean (ms) | 32.11 (range 9–74) | 22.40 (range 5–54) |
| SD | 14.25 | 8.8 |
| *N* | 69 | 204 |

$T(321) = 9.46$, $p < 0.0001$.

The distribution presented in Table 4 indicates that the multiple occlusion variant was most common in word-internal position after /s/, /n/, or /l/, followed by intervocalic position. This variant was less frequent in word-initial position after a vowel and, finally, least frequent in word-initial position after a consonant.

Lastly, given that 18.4% or 69 of the overall native speaker trill tokens were produced as a single occlusion variant (i.e., tap), which is also the main variant produced for intervocalic phonological taps (Rose 2010; Willis and Bradley 2008), we compared the duration of phonological trills produced as a single occlusion to that of phonological taps produced as a single occlusion in order to determine whether this distinction is maintained. In Table 5, the results of an unpaired *t*-test comparing these durations is presented. Although 386 tap tokens were analyzed for native speakers, only 204 contained a clear single occlusion and were included in the duration analysis.

According to the unpaired *t*-test, the duration of native speakers' taps produced in the trill context was significantly longer than that of taps produced in the tap context. Native taps in the trill context had a mean duration of 32.11 ms while those in the tap context had a mean duration of 22.40 ms. The difference in mean duration between the two contexts was 9.71 ms.

## 7.2 Learners

In Figure 10, the overall distribution of trill variants produced by the learners is presented, with the native speaker data included for comparison. Learners used the multiple occlusion variant 10.8% of the time in comparison to the native speakers' 35.1%. Conversely, the learners produced a similar rate of taps as the native speakers, 20.0% compared to 18.4%, and learners produced more native-like approximants (32.1%) than native speakers (18.9%). Assibilated and tap+variants were also produced by learners, at 7.1 and 6.0%, respectively, although native speakers used both variants more frequently, at 12.5 and 14.9%, respectively. Also, learners rarely deleted the trill (1.7%), similar to native speakers. Finally, learners produced two non-native forms: an English-like approximant with a lowered F3 and

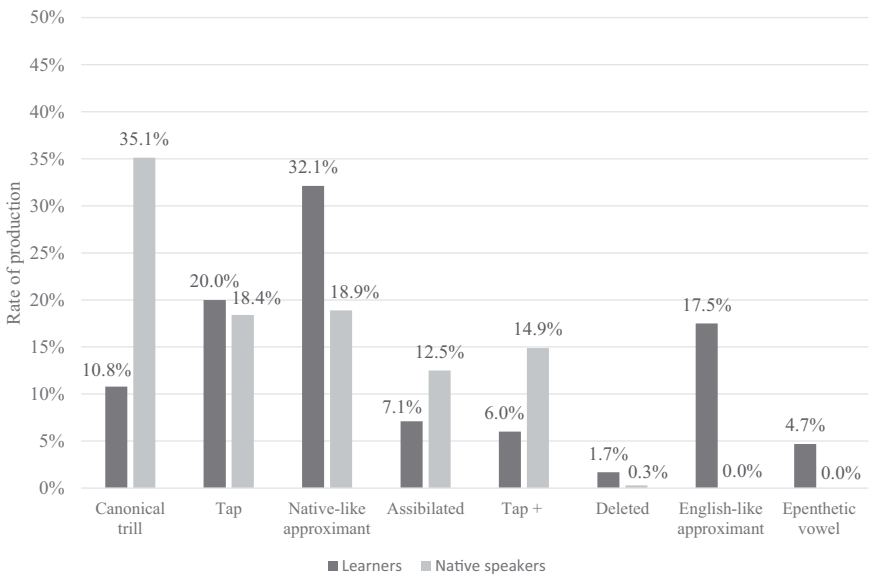


**Figure 10:** Distribution of trill variants in second language and native Spanish.

audible r-coloring for 17.5% of the data and a rhotic with a preceding epenthetic vowel for 4.7% of the data.

Two sets of fixed-effects regression analyses were conducted on the learner data. The first regression examined the factors that affect the use of the canonical multiple occlusion variant as compared to all other variants in learner production. The results from this regression analysis are presented in Table 6. Learners varied in terms of their individual rates of trill production, with a range of 0.0–47.1%

**Table 6:** Factors affecting production of the multiple occlusion variant by learners.

| Factor | *N* | % multiple occlusion variant | Factor weight/log odds |
|---|---|---|---|
| **Following vowel position (*p* = 0.444)** | | | |
| Front vowel | 180 | 16.1% | [0.57] |
| Back vowel | 62 | 16.1% | [0.49] |
| Central vowel | 76 | 14.5% | [0.44] |
| **Speaker sex (*p* = 0.017)** | | | |
| Male | 133 | 21.1% | 0.60 |
| Female | 185 | 11.9% | 0.41 |
| **Log frequency (*p* = 0.001)** | | | 0.848 |
| **Number of higher frequency phonological neighbors (*p* = 0.793)** | | | [–0.027] |

(SD = 16.0). In this regression analysis, all 122 tokens from four learners were excluded since they categorically did not produce the multiple occlusion variant. Two participants were female, with 86 tokens excluded, and two were male with 36 tokens excluded. Thus, four male participants and four female participants were included in the final analysis. There were no other exclusions. This resulted in 342 tokens in the final regression analysis.

As seen in Table 6, the factors that governed the use of the multiple occlusion variant in learner speech differed from those of native speakers. The two significant factors for learners were those of log frequency and speaker sex. For log frequency, the positive log odds indicate that the more frequent the word, the more likely learners were to produce a multiple occlusion variant. Regarding speaker sex, males were more likely to produce the multiple occlusion variant than females. Following vowel position and number of phonological neighbors were not significant for the learners, in accordance with native speakers. Descriptive statistics for preceding segment manner, syllable stress, and position in word, which were not included in the regression, are displayed in Table 7. Additionally, factor weights for preceding segment manner and syllable stress from separate regression analyses are included, as explained in the analysis section. In the analysis with preceding segment manner, only log frequency ($p = 0.002$) and sex ($p = 0.034$) were significant, while preceding segment manner ($p = 0.438$), and number of

**Table 7:** Distribution of the multiple occlusion variant according to preceding segment manner, stress, and position in word in learner speech.

| Factor | *N* | % multiple occlusion variant | Factor weight |
|---|---|---|---|
| **Preceding segment manner** | | | |
| Sonorant consonant | 47 | 25.5% | [0.65] |
| Pause | 54 | 13.0% | [0.52] |
| Low vowel | 75 | 14.7% | [0.49] |
| Mid vowel | 107 | 15.9% | [0.49] |
| High vowel | 32 | 9.4% | [0.35] |
| Obstruent | 27 | 0.0% | [N/A][a] |
| **Stress** | | | |
| Stressed | 83 | 18.1% | [0.50] |
| Unstressed | 232 | 15.1% | [0.50] |
| **Position in word** | | | |
| Word-internal, after /s/, /n/, or /l/ | 5 | 20.0% | N/A |
| Word-initial, after a consonant | 66 | 16.7% | N/A |
| Word-internal, intervocalic | 106 | 16.0% | N/A |
| Word-initial, after a pause | 45 | 15.6% | N/A |
| Word-initial, after a vowel | 115 | 13.9% | N/A |

[a]This category was excluded from the analysis that included preceding segment manner since it is an invariable context.

higher frequency phonological neighbors ($p$ = 0.709) were not significant predictors of canonical trill use. In the analysis with stress, stress was not significant either ($p$ = 0.934) along with higher frequency phonological neighbors ($p$ = 0.635), while speaker sex ($p$ = 0.022) and log frequency were ($p$ = 0.004). Factor weights for preceding segment manner and stress from these regressions are included in Table 7 for comparison with native speakers.

The distribution of the multiple occlusion variant according to preceding segment manner differed between learners and native speakers. Although for both groups, this variant was least frequent after obstruents, for native speakers it was most frequent after low vowels, followed by sonorant consonants, mid vowels, and then high vowels, while for learners, the multiple occlusion variant occurred most after sonorant consonants, followed by pauses, mid vowels, low vowels, and lastly high vowels. Thus, while learners and native speakers were least likely to produce the trill after high vowels and obstruents, their patterning for the remaining preceding segments differed. Additionally, there seems to have been little effect of position in word for learners with only a difference of 6.1% between the context that has the highest rate of the multiple occlusion variant and that which has the lowest. For native speakers, this difference was 16.4%. Additionally, native speakers had the lowest rate of the multiple occlusion variant in word-initial position after a consonant, whereas for learners, word-initial position after a consonant had the second highest rate of multiple occlusion variant use.

The second regression analysis examined the factors affecting the production of native variants compared to non-native variants. The native sounds included the multiple occlusion variant, taps, and native-like approximants, as well as tap+, assibilated, and deleted variants. Non-native sounds were an English-like approximant or a rhotic preceded by an epenthetic vowel. Learners varied regarding their rate of native variants produced, with a range of 41.7–100.0% (SD = 20.0). Data from one female learner were excluded from the regression analysis due to categorical use of native-like variants, which eliminated 34 tokens from the data. The overall rate of native variants in the data included in the analysis was 76.0%. There were no other exclusions. This resulted in 430 tokens from data from five females and six males included in the final regression analysis. The results from the regression analysis are presented in Table 8.

As seen in Table 8, two factors significantly constrained variation: following vowel position and log frequency. Native-like variants were favored by following central vowels, were slightly favored by following front vowels, and strongly disfavored by following back vowels. For log frequency, given the positive log odds, more frequent words favored native-like variants, while less frequent words favored more non-native variants. Speaker sex and number of higher frequency phonological neighbors were not significant.

**Table 8:** Factors affecting the use of native versus non-native variants by learners.

| Factor | *N* | % native | Factor weight/log odds |
|---|---|---|---|
| **Following vowel position ($p < 0.001$)** | | | |
| Central vowel | 98 | 88.8% | 0.68 |
| Front vowel | 232 | 76.7% | 0.52 |
| Back vowel | 100 | 62.0% | 0.31 |
| **Speaker sex ($p = 0.160$)** | | | |
| Female | 254 | 78.0% | [0.54] |
| Male | 176 | 73.3% | [0.46] |
| **Log frequency ($p = 0.005$)** | | | 0.581 |
| **Number of higher frequency phonological neighbors ($p = 0.917$)** | | | [0.007] |

In Table 9, the distribution of native-like variants according to preceding segment manner, stress, and position in word is presented. As explained in Section 6.3 and for the first learner regression analysis, preceding segment manner and stress were run in separate regression analyses, replacing following vowel position. Results showed that preceding segment manner ($p < 0.001$) and stress ($p = 0.040$) were significant in the analyses in which they were included. Frequency was not significant for the run including preceding segment manner ($p = 0.053$), but was significant for the run with stress ($p = 0.04$). Number of higher frequency phonological neighbors was not significant in any analysis. For preceding segment manner, native-like variants were most frequent after all vowels in the following order: low, mid, then high vowels. They were less frequent after consonants and pauses, with post-pause as the context with the lowest amount of native-like variants. The hierarchy was similar to native speakers with the exception of sonorant consonants, which favored the trill for native speakers. Regarding stress, unlike for native speakers, for whom stress had little effect on variation, learners were more likely to produce native-like variants in unstressed syllables compared to stressed ones. For position in word, trill phonemes in intervocalic position were more likely to be native-like, followed by all word-initial trills, while trill phonemes in word-internal position following /s/, /n/, or /l/ were less likely to be native-like.

Lastly, in Table 10, results are presented for an unpaired *t*-test comparing the duration of one-occlusion variants (i.e., taps) produced in the trill context, which comprised 20.0% of trill tokens, to the duration of one-occlusion variants produced in the tap context. Learners produced a range of variants in the tap context, including non-native English-like approximants and native-like single occlusion taps. Of the 357 tap phoneme tokens analyzed, 149 had a measurable single occlusion and were included in the duration comparison.

**Table 9:** Distribution of native-like variants according to preceding segment manner, stress, and position in word in learner speech.

| Factor | *N* | % native-like variant | Factor weights |
|---|---|---|---|
| **Preceding segment manner** | | | |
| Low vowel | 107 | 86.0% | 0.69 |
| Mid vowel | 136 | 83.8% | 0.64 |
| High vowel | 34 | 76.5% | 0.53 |
| Sonorant consonant | 56 | 67.9% | 0.42 |
| Obstruent | 31 | 64.5% | 0.39 |
| Pause | 66 | 56.1% | 0.33 |
| **Stress** | | | |
| Unstressed | 306 | 78.1% | 0.57 |
| Stressed | 124 | 71.0% | 0.43 |
| **Position in word** | | | |
| Intervocalic | 97 | 95.9% | N/A |
| Word-initial, after a vowel | 102 | 77.5% | N/A |
| Word-initial, after a consonant | 57 | 77.2% | N/A |
| Word-initial, after a pause | 42 | 71.4% | N/A |
| Word-internal, after /s/, /n/, or /l/ | 5 | 40.0% | N/A |

**Table 10:** Duration of taps produced in trill contexts and in tap contexts by learners.

| | Tap in trill context | Tap in tap context |
|---|---|---|
| Mean (ms) | 32.59 (range 9–68) | 22.20 (range 5–62) |
| SD | 15.4 | 11.18 |
| *N* | 93 | 149 |

$T(240) = 6.07$, $p < 0.001$.

According to the unpaired *t*-test, learners produced significantly longer taps in the trill context, with a mean duration of 32.59 ms, than taps produced in the tap context, which had a mean duration of 22.20 ms. The difference in tap duration between the two contexts was 10.39 ms, which is similar to the native speaker difference of 9.71 ms.

# 8 Discussion

In this section, the results of the current study are discussed in light of the research questions as well as findings in the L2 acquisition of phonology. The first research question pertained to the distribution of trill variants by L2 learners and how their

distribution compared to that of native speakers. The findings for this study indicate that while native speakers and learners do produce many of the same variants in the trill context, their distributions differ and not all variants overlap between the participant groups. For native speakers, the most common variant was the multiple occlusion trill and the second most frequent was a native-like approximant, followed closely by the tap. For the learners, native-like approximants, taps, and English-like approximants were all more frequent than multiple occlusion trills. The high rate of tap use by learners is consistent with findings by Face (2006), Rose (2010), and Waltmunson (2005), who reported that the tap was either the most common or second most common variant produced by advanced learners for /r/. The less frequent use of an English-like approximant with a lowered F3 and audible r-coloring is also consistent with these studies, which found that learners at an advanced level produced this non-native sound less than the tap. Learners' frequent use of the native-like approximant, however, has not been documented in previous research. This may be in part because of different ways of coding trill variants between studies, as well as our decision to conservatively categorize tokens with unclear or incomplete occlusions but consistent formant structure as approximants. The variant we defined as a rhotic preceded by an epenthetic vowel also differs from previous studies, which have not documented this form. It occurred relatively rarely in our data and most often after a pause, perhaps due to learners' attempt to create a more conducive articulatory environment for a trill, given that a voiced alveolar trill is essentially "a vocalic sound interrupted by a rapid sequence of abbreviated stops" (Widdison 1998: 57). In terms of other variants, learners had somewhat lower rates of production of assibilated and tap+variants compared to native speakers, and about the same low rate of elision. Taken together, these findings indicate that in 77.8% of trill contexts learners produced variants also produced by native speakers. Thus, while learner productions in the trill context were not target-like when solely looking at the rate of multiple occlusion variant production, they appeared more native-like when considering all variants that native speakers used.

The second research question concerns the factors that govern trill variation in native speakers and learners, and how these factors compare. When considering what factors predicted the use of the multiple occlusion variant, it is clear that the learners' production was not conditioned in the same way as native speakers' production. Native speaker trill variation was governed only by preceding segment manner while this factor did not affect learner production. On the other hand, learners' production of the multiple occlusion trill was affected solely by log frequency and sex, and these effects were different from that found in most previous research. For the learners, higher frequency was associated with more multiple occlusion trill production. Additionally, the analysis of learners' use of native versus

non-native variants showed that learners were more likely to produce native-like variants as a whole in higher frequency words. Although there was no effect of frequency on the production of trills for the native speakers in the current study, other studies have found that native speakers are less likely to produce the multiple occlusion trill in more frequent words (Lamy 2015; Zahler and Daidone 2014), which is consistent with the usage-based principle of phonetic reduction in more frequent articulatory patterns (Bybee 2002). It merits mention that Melero García (2018) reported an unexpected opposite effect to that evidenced in Lamy (2015) and Zahler and Daidone (2014). While the reason for this is unknown, it appears that he did not include phonetic context in his regression analysis, so perhaps this effect is due to an interaction between the frequency and phonetic structure of words. In any case, in contrast to the native speakers in Lamy (2015) and Zahler and Daidone (2014), it is possible that the opposite effect of frequency for the L2 learners in the current study reflects a practice effect. More frequent words are heard and produced more often, which might aid L2 learners of Spanish in producing them with the multiple occlusion trill and other native-like variants.

Although speaker sex was not significant for the native speakers in our study, native speaker research on trill variation has found that women are more likely to produce the multiple occlusion variant or other prestige forms compared to men (e.g., Díaz-Campos 2008; Henriksen 2014). Previous studies examining learner Type II variation have found that female non-native speakers tend to produce the standard or prestige variant more often, such as *-ing* [ɪŋ] instead of *-in'* [ɪn] for English (ing), in line with results for native speakers (e.g., Adamson and Regan 1991). In terms of Type I variation, Díaz-Campos (2004) found that female learners were more native-like than male learners for a number of Spanish sounds. Thus, it was expected that our female learners would produce more multiple occlusion variants and native-like sounds than male learners. The opposite effect was found for the learner multiple occlusion variant versus all other variants analysis and no effect was found in the learner native-like versus non-native analysis. However, only eight participants (four female and four male) were included in the first analysis due to exclusions. Moreover, individual learners demonstrated a wide range of rates of production of the multiple occlusion variant (0–47.1%). Additionally, one female participant who categorically produced native-like variants was excluded in the second analysis. Thus, it may be that our findings differed from previous research due to small numbers of participants in our learner analyses.

When we grouped all variants that native speakers produced and consider them native-like for the learners, we found that learners produced more native-like variants in contexts where native speakers produced the multiple occlusion trill more frequently, while also finding that some contexts differed. In the second

learner analysis, phonetic context and frequency were important for learners' use of all native-like productions. Following vowel position was significant for the learners; the central vowel /a/ favored native variants while front vowels /i/ and /e/ neither favored nor disfavored their use, and back vowels /u/ and /o/ disfavored. Despite the fact that following vowel position was not significant for native speakers, their distribution of multiple occlusion trills according to these categories mirrored that of the native variants for learners, with more of the multiple occlusion variant before /a/ than front vowels and back vowels, respectively. Furthermore, preceding segment manner was significant for native speakers, and although preceding segment manner could not be included in the learner regressions due to interactions, when included in its own analysis instead of following segment position, it was significant. Native speakers and learners demonstrated several similarities for this factor. First, low vowels strongly favored the use of the multiple occlusion variant for native speakers and native-like variants for learners, while obstruents disfavored both. Mid vowels also favored both. Native speakers and learners differed regarding sonorant consonants, which strongly favored the multiple occlusion variant for native speakers, and somewhat disfavored native-like variants for learners. Lastly, high vowel contexts were slightly different for the two groups, but since the factor weight was near 0.50 in both regression analyses, this context did not seem to exert a strong influence on trill variation for either group. These findings for phonetic context generally mirror previous research on native speaker trill variation, in that /a/ is more conducive to multiple occlusion trill production than /i/ or /u/ (Henriksen 2014; Solé 2002), while a preceding obstruent like /s/ disfavors the multiple occlusion trill (Bradley 2006; Diez Canseco 1997; Lewis 2004). In contrast, when examining the distribution of solely the multiple occlusion variant according to preceding segment manner for learners, many more differences between learner patterns and those of native speakers were evident. Learners produced the multiple occlusion variant most frequently after preceding sonorant consonants, and although low vowels were the context with the highest rate of multiple occlusion variants for native speakers, it was the context with the fourth highest rate of this variant for learners. Overall, it appears that phonetic environments that are conducive to multiple occlusion trill production for native speakers are also the environments in which learners are better able to produce a native-like variant, but not necessarily a multiple occlusion trill, except for the context of a preceding sonorant consonant. Interestingly, although not included in the final analysis, when run in a separate regression instead of following vowel position, syllable stress was significant for the learners. They were less likely to produce native-like variants in stressed contexts and more likely to produce them in unstressed contexts. This finding differed from our native speakers, for whom this factor was not significant.

Given the frequency of tap production in trill contexts in both the native speaker (18.4%) and learner data (20.0%), the third research question asked whether learners maintain a tap-trill distinction via duration as evidenced for native speakers in previous research (Bradley and Willis 2012; Henriksen and Willis 2010; Willis and Bradley 2008). The findings indicate that learners and native speakers both maintained a statistically significant average difference in duration for taps produced in the tap context and those produced in the trill context, although the difference was minimal, with a 9.71 ms difference for native speakers and a 10.39 ms difference for learners. It is unclear whether these differences would be useful for disambiguation or if they are even perceptible, especially given that the range of durations produced by both learners and native speakers indicates that there is a large overlap in duration between the two contexts. Furthermore, an average closure duration of 32.11 ms for native speakers and 33.63 for learners for taps in the trill context is a much shorter occlusion than what is necessary for a tap to be reliably perceived as a trill. Melero García and Cisneros (2020) investigated how differences in the duration of the occlusion affected the identification of words in tap-trill minimal pairs. To create their duration continuum, the researchers recorded native Spanish speakers saying words containing an intervocalic tap, then manipulated the closure duration of the tap in increments of 10–15 ms. They found that for native listeners, the higher the duration of the closure, the more likely listeners were to choose the trill, with the crossover point to a higher probability of trill selection around 65 ms. This crossover point is closer to what has been evidenced for native speaker production of taps in the trill context in previous research (Henriksen and Willis 2010), which found average duration measurements of one-occlusion phonemic trills to be 66 ms compared to the 32.11 ms observed in the current study. This difference from previous research is likely because in this study we measured only trills realized as simple taps, whereas in the study by Henriksen and Willis, it appears that the full durations of all one-occlusion variants (the equivalent of tap+ in this study) were included in the analyses. Future research that measures the duration of one-occlusion trills that are purely taps is needed to determine if methodological differences are the cause of divergent findings.

Overall, these results indicate that although learners do not exhibit a native-like multiple occlusion trill rate or native-like predictors of trill use, learners do maintain a tap-trill distinction and demonstrate variation that is similar to that of native speakers in several respects. All learners displayed use of multiple native-like variants, even if they produced no tokens of the multiple occlusion variant. If only the multiple occlusion trill is considered target-like, then the learners in the current study appear to have made little progress in accurately articulating the trill, since they only produced the multiple occlusion variant 10.3% of the time.

However, when considering their production in light of all other sounds that native speakers also produced, their use of a non-native variants only accounted for 22.2% of tokens. This finding does not mean that learners were native-like the remaining 77.8% of the time, since they produced other native trill variants at different rates than native speakers did, particularly the native-like approximant. Learners' overuse of the native-like approximant and similar rate of tap use may be because these sounds are articulatorily easier to produce than a multiple occlusion trill, which can only be realized under precise aerodynamic conditions (Solé 2002). This developmental step would not be surprising since the tap phoneme is acquired before the trill phoneme in Spanish-speaking children (Jimenez 1987). Also, Spanish-speaking children between 3 and 6 years old frequently use a tap variant when producing the trill phoneme, and children between 7 and 10 who have difficulty with the trill often produce approximant variants with no occlusions and only a small difference between the intensity of the consonant and the surrounding vowels (Carballo and Mendoza 2000). Additionally, previous L2 research on Spanish trill acquisition has shown that learners often produce the tap in trill contexts (Face 2006; Rose 2010; Waltmunson 2005). Taken together, these findings indicate that the frequent use of other variants such as the tap and native-like approximant "may be a necessary stage in the acquisition of rhotics in Spanish" (Rose 2010: 283). This suggests that although learners may be sensitive to factors governing native speaker variable trill production, their progress toward the native speaker norm may be constrained in part by the articulatory difficulty of the multiple occlusion trill. This finding is supported by the fact that frequency was significant in both learner regression analyses. Higher word frequency favored both higher rates of the multiple occlusion variant, as well as more frequent use of all native variants together, suggesting a practice effect. However, future research of learners at various proficiency and experience levels, as well as longitudinal research, would be needed to support this suggestion. Additionally, future research examining a larger number of learners would be necessary to ensure that the patterns found in the current study are not specific to this group of individuals, but rather indicative of learner behavior on a larger scale.

# 9 Conclusion

The current study sought to apply the variationist method to the study of L2 trill production by advanced learners of Spanish. We found that learner variation in trill production is systematic and conditioned by several of the same factors that govern native speaker variation. Results indicated that learners produced native variants, both the multiple occlusion trill and other native realizations, in many of the same

contexts that favored the multiple occlusion variant in native speakers. Similarly, learners were most likely to produce a non-native variant in the phonetic contexts where native speakers were also less likely to produce the multiple occlusion variant. Moreover, learners maintained a distinction in duration between taps produced in a phonological tap context and taps produced in a phonological trill context, although this average duration difference was small for both native speakers and learners. At the same time, differences in the distribution of trill variants produced as well as the effect of frequency and stress show that learners differed from native speakers in several ways. Learners' overuse of the native-like approximant and frequent use of the tap, coupled with previous research, suggests that learners' use of other native variants in the trill context may be at least in part attributable to an intermediary step in the acquisition of the canonical multiple occlusion trill. Furthermore, learners produced more multiple occlusion trill as well as other native trill variants in more frequent words, suggesting a practice effect.

Our study provides a snapshot of learner behavior at one experience level, that of advanced learners who have studied abroad for a year. However, since it is not longitudinal or cross-sectional, we can only infer what our findings suggest about learner development. To continue to study the L2 acquisition of Spanish rhotics, and to accurately characterize the range of sounds produced in the process of acquiring the trill, further research is needed that examines the variants used by learners across L2 proficiency levels and the factors that predict their production at each level. It is also important to highlight that because data from more open-ended speaking tasks are often complicated and difficult to analyze statistically due to interactions between the different variables, a future study would be useful in which learners and native speakers produce words controlled for a number of these linguistic factors. In such a study, the effects of variables such as frequency, preceding segment, following segment, and stress could be tested independently and without interactions. Nevertheless, our findings demonstrate that variationist analyses of L2 sound production can provide insight into learners' phonological systems.

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