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L2 perception of Spanish palatal variants across different tasks

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Abstract

In most varieties of Spanish, the palatal affricate [ɟʝ] tends to occur in word onset following a pause and in specific linear phonotactic environments (following a nasal or a lateral); the palatal fricative [ʝ] tends to occur in syllable onset in other contexts. While considerable dialectal variation exists in terms of their actual realization, almost all varieties of Spanish exhibit some sort of alternation in terms of the palatal segments. In the present study we show L2 Spanish listeners' perceptual sensitivity to the palatal alternation depends upon the task. Specifically, for Native Spanish listeners, the presence of the palatal alternation boosts segmentation accuracy on an artificial speech segmentation task and also reduces latencies on a phonotactically-conditioned word-spotting task. L2 Spanish listeners, on the other hand, only benefit from the presence of the palatal alternation in the second task. These results suggest that while Spanish L2 learners benefit from the presence of the alternation in linear phonotactic terms, this benefit does not carry over to a more abstract segmentation task. In other words, L2 learners may not exploit the same information when carrying out distinct speech processing tasks.

187 words

1. Introduction

Second language learners are faced with a difficult task when acquiring another language. They must detect and learn the words of the other language while managing their already established native linguistic system. This task is even more difficult when we take into account the variability present in the speech signal. Variability can be indexical in nature (due to individual speaker characteristics) or phonotactically conditioned. Thus, part of learning a language involves processing a highly variable signal and recognizing that certain variability is distributionally conditioned. For example, certain sounds will occur in some phonotactic contexts and not others, information which native speakers can exploit to carry out various speech processing tasks. In the present study, we examine how adult second language learners do this, that is, whether they can use such contextually-conditioned alternations in the same way as native speakers. Specifically, we examine second language learners' ability to use the palatal obstruent variants in Spanish to segment the speech stream and to spot words when the phonotactic conditions are favourable.

Studies examining perception of the same perceptual target – in this case the palatal variants – across different tasks afford a unique perspective on the development of a second language sound system by shedding light on how different task demands influence performance. In experiments 1 and 2, we examine how English phonological relationships and phonetic cues play into the way L1 English/L2 Spanish listeners perceive the palatal alternation. In experiment 3 participants carried out an artificial language segmentation task in which we varied the presence of the palatal variant. Finally, in experiment 4, participants had to listen for real words embedded in a context syllable where the coda segment either favoured or disfavoured, in phonotactic terms, the palatal onset that followed. Together, these experiments paint a picture of how L2 learners perceive and make use of the information in the speech signal across a variety of different tasks.

1.1 Palatals in Spanish and English

Spanish attests numerous palatal and palatoalveolar phonetic categories, graphically corresponding to *ll* (e.g., *llave* ‘key’), *y* (*playa* ‘beach’) and *hi*(*e*) (*hierro* ‘iron’). Within the continuum of palatal consonants one finds in Spanish the palatal approximant [j], voiced fricative [ʝ], voiced plosive [ɟ] and voiced affricate [ɟʝ]. Dialectal, idiolectal and stylistic/register differences may in some instances result in the voiced palatoalveolar affricate [dʒ], or either the voiced [ʒ] or voiceless [ʃ] palatoalveolar fricative (especially in Argentina and Uruguay) (see Hualde, 1997, 2005 for background literature). The current study is, however, primarily concerned with the palatal variants, specifically the fricative and affricate.

The palatal alternants tend toward complementary distribution determined in part by three linguistic factors: prosody, the preceding segment and word position. The likelihood of either the approximant [j] or fricative [ʝ] is higher in unstressed syllables, while stressed syllables favor strengthening, resulting in either the fricative [ʝ] or affricate [ɟʝ]. The surrounding phonetic context, specifically the preceding sound, also influences the alternation. The approximant and fricative are more likely in post-vocalic position, while post-pausal, post-nasal and post-lateral positions favor the affricate or even the palatal stop [ɟ]. Word-internal position (medial or final) increases the probability of the approximant and fricative, while the affricate and stop are more likely to appear in word-initial position.

While not directly relevant to the study at hand, external factors such as speech rate, register and formality also affect the alternation. Faster and/or informal speech favors the approximant and fricative while slow, monitored, formal and/or emphatic speech increases the likelihood of the affricate and stop variants. As has been implied throughout this discussion, this is not to say, for example, that the approximant is categorically barred from contexts that tend to favor the affricate, or vice versa. To the contrary, every variant from the Spanish palatal continuum is *possible* in any given context, yet particular contexts seem to *favor* one variant (or one end of the continuum) relative to the other. The empirical goal of the present study is therefore to determine if native and L2 listeners use these *tendencies* in speech segmentation and word recognition tasks. For example, we will argue in more detail in sections 4 and 5 that such tendencies aid word segmentation in Spanish; the likelihood of encountering a word boundary when presented with a palatal affricate or stop is higher than when presented with either the fricative or approximant given that word-initial position *favors* the stop or affricate relative to the fricative or approximant. Even though the fricative and approximant are both *possible* in this position, their appearance is *less likely* compared to the likelihood of, for example, the affricate, even in running/connected speech (Piñeros, 2009, p. 207).

The fact that the three linguistic factors are interact and cannot be applied independently further confirms that the alternation is one of general tendencies and not categorical absolutes; the issue is compounded when the external factors are also considered in natural speech outside of the empirical setting. To take as examples, consider *una llave* ‘a key’ and *cónyuge* ‘spouse.’ In the first case, the palatal segment orthographically corresponding to *ll* is stressed and word-initial, two factors that suggest the likelihood of a stop or affricate. On the other hand, it is simultaneously post-vocalic, which otherwise tends to favor the approximant or fricative. In the second case, the palatal segment, here represented by *y*, is internal and unstressed, both of which are normally associated with the approximant or fricative. Phonetically, however, it is post-nasal, which favors strengthening to the stop or affricate. It is this confluence of factors that demonstrates why any given alternant might be possible in any given position. Even so, tendencies such as those discussed above can still be made about the data; the present study seeks to determine if the two groups of listeners can apply these tendencies to the four tasks that we conducted.

In the case of the L2 group, knowledge of the palatal alternation is a question of acquisition that we pursue experimentally considering that it is not 'transferable' from English. English contains at least four palatal phonetic categories: vocalic tense [ii̯] and lax [ɪ], approximant [j], voiced [ʒ] and voiceless [ʃ] palatoalveolar fricatives and voiced palatoalveolar affricate [dʒ]. At the moment we are only concerned with the palatal approximant [j] and palatoalveolar affricate [dʒ] in comparing the two systems as our L2 learners were not exposed to the Argentinean/Uruguayan Spanish dialects that employ [ʒ] and [ʃ], nor was our test stimuli representative of such dialects. Unlike Spanish, however, English palatals do not exist in a continuum and are not representative of predictable variants, as substituting one palatal for another in a given word runs the risk of changing the meaning. Both the approximant [j] and affricate [dʒ] can appear in initial stressed (*yet*, *jet*), initial unstressed (*yourself, judgmental*), internal stressed (*beyond, pajamas*) and internal unstressed (*kayak, major*) positions. Furthermore, the preceding segments play no role, as both freely appear in post-vocalic (*a year, a jeer*), post-nasal (*unyielding, enjoin*) and post-lateral (*all year, all jeer*) positions. Additionally, the palatoalveolar affricate [dʒ] is a possible coda segment in English (*bridge*)[1], which is categorically impossible in Spanish.

To summarize, given that English palatals [j] and [dʒ] are not predictable based on position, do not exist in a continuum and are not interchangeable without semantic consequence, the L2 Spanish learner coming from English is faced with the task of acquiring novel phonetic categories (palatal fricative, affricate and stop) and recognizing that, although each palatal segment is *possible* in all positions, not unlike English, each position tends to *favor* one category over the other, a fact for which English offers no guidance.

For the purposes of this paper, the positing of an underlying form is not necessary. We assume that the occurrence of either the less-consonant-like [ʝ] or the more consonant-like [ɟʝ] is due to where in the word or phrase the sound occurs. Moreover, as stated above, the alternation is non-categorical in nature. Indeed, in probabilistic terms, the affricate alternant will be more likely to occur in phrase-initial position and the fricative alternant in word-medial position but this is never 100% and will depend, as stated above, upon phonotactics, orthography and dialectal variation. It is possible to observe the distinct phonetic realizations of the palatal glide

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[1] The palatal approximant [j] may or may not be a possible syllable-final segment depending on one's theoretical assumptions about English and transcription convention. While some researchers prefer [j] in transcribing the English diphthongs [aj], [ej] and [ɔj], thus allowing [j] as a syllable-final segment (e.g., *buy*, *bay* and *boy*, respectively), others prefer [ai̯] or [aɪ̯], in which case [j] is confined to onset position only. In either scenario the traditional assumption is that the palatal segment in question is vocalic in nature, and is thus not directly comparable to [dʒ] in *bridge*, which is unambiguously a coda consonant.

and fricative/affricate/obstruent segments. Aguilar (1998) provides average measurements of the glide and high front vowel, as produced by Castilian Spanish speakers. She found that the glide [j] is shorter than the vowel (an average of 110ms vs. 82ms, respectively) and with higher F1 and lower F2 values. According to Martinez-Celdran and Fernandez-Planas (2007), there are only two obstruent palatal phones in Spanish, [j̥̞] and [ɟj̥̞)] and one palatal semivowel [j]. The first is an approximant, manifesting little if any frication in its articulation while for the second segment, the authors prefer to call it a double articulation, rather than an affricate, given that the second element does not exhibit the frication that accompanies the release of the stop.

Nonetheless, our goal was to investigate whether learners are aware of the role played by the affricate variant in indicating word-onsets, rather than recognizing the difference between the two variants and their positional restrictions. Thus, even though both variants can probabilistically occur in word onset, the affricate is highly unlikely to occur in word-medial, intervocalic position, suggesting that it plays a strong role in recognizing potential onsets to lexical candidates in Spanish.

1.2 L2 Speech perception and allophonic variants

Knowledge of positional restrictions on alternations involves recognizing that two sounds are related more closely to each other than non-alternating sounds and furthermore, recognizing the context in which each is likely to occur. In the present case, one alternant, [ɟj̥] is more closely linked to specific boundary information in the signal. Research has shown that the pattern of allophonic alternations in the listener’s native language influences speech perception (Boomershine, Hall, Hume & Johnson, 2008; Dupoux, Pallier, Sebastián-Gallés & Mehler, 1997). In a study directly related to English and Spanish, Boomershine et al. (2008) investigated the perception of [d], [ð] and [ɾ] by speakers of Spanish and English. In English, [ɾ] and [d] may alternate with each other while [ð] does not alternate with either; in Spanish, on the other hand, [ð] and [d] alternate while [ɾ] is contrastive. Boomershine et al. found that English listeners rated [ɾ] and [d] as more similar to each other than Spanish listeners did, while [ð] and [d] were more similar for Spanish listeners than for English listeners. In a subsequent speeded discrimination task, Boomershine et al. (2008) found that these cross-linguistic patterns of perceptual similarity also held. The authors concluded that the phonological relationships that hold in the listener's native phonological inventory play a determining role in speech perception.

The results from Boomershine et al. show that L1 segmental relationships affect L2 perception. However, such alternations are by definition conditioned by the environment in which they occur and experienced listeners can take advantage of this probabilistic knowledge when carrying out speech perception tasks. One area where this knowledge is particularly useful is in the segmentation of the continuous speech stream. An extensive body of research has shown that infants and adult learners use all types of information in their search for word boundaries. While different segmentation heuristics are available, one particular mechanism has been shown to operate across all groups studied so far: the tracking of statistical information, such as transitional probabilities (TPs: Saffran, Aslin & Newport, 1996). The essential logic behind tracking TPs is that within-word probabilities across syllables are higher than across-word probabilities, and where a probabilistic trough occurs, the listener assumes a word boundary has been encountered.

Researchers have recently begun to explore how such a mechanism might operate in adults acquiring a second language. One key issue revolves around how previous learning potentially interferes with tracking a new set of statistical relations and how separate statistical relations between languages are maintained. Current work shows that in general, listeners exposed to two different 'languages' (distinguished by different TPs) require either indexical information (Weiss, Gerfen & Mitchel, 2009) or pauses and explicit instruction (Gebhart, Aslin & Newport, 2009) to inform them that there were two separate sets of statistics to be tracked.

Previous learning can also affect the way in which statistics are calculated across the input. For example, language-specific phonotactic knowledge can affect the way in which TPs are tracked and such knowledge, accumulated over years of experience with a native language, may impede successful storage and tracking of new regularities in the input. Research by Finn and Hudson Kam (2008) examined how native language phonotactic knowledge drives the segmentation of an artificial language stream by native English speakers. In their study, listeners preferred words that violated transitional probabilities but respected phonotactic regularities when tested on both after exposure to an artificial language stream. The authors interpret this finding to mean that linguistic knowledge takes priority over whatever statistical mechanism may be at work in speech segmentation. In other words, the tracking of transitional probabilities can be boosted by the presence of additional cues that may assist with segmenting the speech stream. More importantly, when such phonotactic cues are violated, listeners are prevented from successful segmentation altogether. Tyler nd Cutler (2009) examined the role of prosodic cues in artificial speech segmentation by listeners of differing L1s. Their findings suggests that both language-universal (final vowel lengthening) and language-specific (pitch movement) information affected segmentation by native Dutch, English and French listeners.

The evidence suggests that both TP and phonotactic knowledge likely emerge from a distribution-based learning mechanism. However, there are important differences in terms of where these statistics come from. Using phonotactic knowledge for speech segmentation involves the application of generalized knowledge taken from specific instances (typically assumed to be type frequencies across the lexicon; see Pierrehumbert, 2006) and applying it to potential word forms. As Finn and Hudson Kam (2008) argue, while phonotactic knowledge reflects input to which learners have been exposed over the course of their language experience, TPs do not necessarily reflect such long term knowledge and can be easily manipulated over the short term.

In our third experiment, participants were exposed to an artificial language based upon a ‘new variety of Spanish’ that either contained the palatal alternation or did not. Subsequently, they were tested on their ability to judge which member of a pair of words occurred in the language. We hypothesized that the native Spanish speaking group would benefit from the presence of the palatal alternation to a greater extent than the L2 Spanish group given their familiarity with the allophonic alternation in their native language.

In experiment 4 we tap into another type of probabilistic knowledge, that of phonotactics. We examine whether native and L2 Spanish listeners recognize palatal-initial real words more quickly when they are preceded by context syllables ending in segments which favour the following palatal variant. For example, context syllables ending in vowels will favour fricative onsets for the adjacent word while those ending in nasals or laterals will favour affricate-initial words. Again, we varied the onset palatal to follow phonotactic expectations (alternating condition) or not (non-alternating condition). We hypothesize that native Spanish speakers will perform faster and more accurately on those items exhibiting the palatal alternation (i.e., that follow the phonotactic probabilities) than on those which do not. For the L1 English/L2 Spanish group, it is possible that no difference between the two conditions emerges.

Some evidence for this prediction comes from Weber and Cutler (2006). They examined how such boundary effects play out in a word spotting experiment with highly proficient L1 German/L2 English and Native American English speakers. The stimuli consisted of embedded English or (different condition) German words. They found that accuracy and response latencies were facilitated by boundaries that coincided with word-onset phonotactics for both languages (e.g., ‘wish’ in *yarWISH* versus *plookWISH*) and boundaries that only occurred in English facilitated recognition by both groups, albeit to a lesser extent for the native German speakers.

The experiments reported on here help elucidate how the task at hand modulates the performance of L2 listeners and thus how information that is available for one task may or may not be available for another.

2. Experiment 1: similarity rating task

In experiment 1, Native Spanish and L2 Spanish listeners heard pairs of nonwords that varied on the position and type of palatal variant and had to rate their similarity. The objective is to determine how language-specific perception affects the perceived similarity of two sounds that exhibit different relations of contrast across listeners’ first and second languages. Based upon previous work showing that the pattern of phonological relations between sounds in a listener’s native language plays a strong role in how listeners rate their similarity (Boomershine et al, 2008; Johnson & Babel, 2007; 2010), we predict that the native Spanish listeners will rate minimal pairs of nonwords with the palatal alternants as more similar than the L2 listeners, given the L2 listeners’ limited experience with Spanish.

2.1 Participants

Twenty-nine native (Mexican) Spanish speakers (NSS, 17 males, 12 females) participated in the experiment. They were recruited from the Center for Foreign Language Teaching at the National Autonomous University of Mexico (CELE-UNAM). They received $10.00 for their participation in the experiment. Thirty L1 English/L2 Spanish listeners (L2 Spanish) were recruited from the University of Iowa. They received course credit for their participation. Biographical information on both groups of participants is presented in Table 1.

Table 1. *Biographical information*.

Insert Table 1 here

The two groups were similar in terms of age and years of studying their second language. None of the participants had lived in a country where their second language was spoken for a period longer than two weeks and none interacted in their second language outside the classroom. In Mexico (particularly Mexico City) it is difficult to find university-level students who do not listen to music or watch television in English. Nonetheless, care was taken to ensure that they were not exposed to more than a few hours a week. The L2 Spanish group did not listen to Spanish music or watch Spanish television outside of their classes. In terms of Spanish varieties, the L2 listeners were typical of college-level learners, in that they had been exposed to a wide variety of different accents over their course of study, with no particular variety being dominant for any of the learners.

2.2 Stimuli

A native female Mexican Spanish speaker recorded the stimuli. She read each word three times and the clearest tokens were spliced out and used for the experimental stimuli. The target stimuli consisted of six CV.CV or six V.CV bisyllabic words. The CV.CV items took the form of CV-*ma* (e.g., [ɟʝama] ~ [ʝama]), where onsets were either [ʝ] or [ɟʝ], combined with the vowels [a o u]. Tokens were produced with stress on the initial syllable. For the V.CV target items, the palatal sounds were combined with three vowels [a o u] (e.g., [uʝa] ~ [uɟʝa]). For the fillers, the onsets consisted of [s l r], which were combined with the vowels [a o u]. Stress was uniformly produced on the first syllable.

Stimuli were checked to guarantee that target segments in different positions shared the same acoustic properties. To this end, each of the affricate and fricative targets – in initial and medial positions – were measured and compared based upon their phonetic characteristics. For the affricate targets, we noted the amount of frication following the stop release, the overall segment duration and the presence (if any) of a release burst from the stop portion of the affricate. We further measured the intensity of the stop release burst relative to the intensity of the following vowel to factor out the effect of the differences in overall intensity across tokens. Burst intensity (dB) was subtracted from the vowel intensity (Sundara, 2005). A greater intensity difference will result with softer bursts, indicating a weaker release on the stop. For the fricative targets, we measured the segment duration and the intensity compared to the following vowel. In Table 2 we present the differences between the average values for each of the target token segments in onset and medial positions:

Table 2. *Acoustic information for experiment 1*

Insert Table 2 here.

As can be seen from these acoustic measurements, the target segments were produced almost identically in onset and medial position. Moreover, as indicated by the presence of a release burst in the affricate segments, lower intensity ratios and shorter durations, we can also safely assume that the affricates were indeed distinct from the fricative targets. In Figure 1 we present examples of the stimuli used in experiment 1 (and experiment 2, see below):

Figure 1. *Examples of stimuli used for experiment 1.*

Each token was combined into either a “same” or “different” pair taken from the same category, whether CV.CV or V.CV. For the same pairs, different tokens of the same item were presented. For the different pairs, different versions of the alternation were used, whether the affricate or fricative. In Table 3 we present the composition of the experimental trials.

Table 3. *AX rating task trials*.

Insert Table 3 here

Given the form of the stimuli, some were real words in Spanish.[2] There were a total of 36 trials (24 different, 12 same target word). The interval between each member of the pair was 500ms.

2.3 Procedure

The stimuli were presented in pairs using a Macbook Pro computer running Superlab experimental software. After the trial pair offset, participants had 3500ms to circle the number on a sheet of paper that corresponded to their judgment of the two words: 1 signified that the words in the pair were "the same" and 5 meaning that the two stimuli in the pair were the "very different". The trials were randomized for each participant. Participants were given three practice trials before beginning. Practice items were not taken from the test trial items.

In an effort to have both groups listening in Spanish, they were told that the items were based upon possible words and combinations of sounds from that language. Their task was to decide how similar the two words were based upon the sounds in each. All communication with participants occurred in Spanish in an effort to guarantee that the L2 Spanish participants were carrying out all tasks in Spanish.

2.4 Results

All rhotic items were subsequently dropped because of inconsistent results. [3]

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[2] Some of the trials included real words (e.g., *olla* 'pot', see Table 3). To remove possible lexical effects, we ran the same statistical analyses without the tokens that were possible words in Spanish and the results were consistent.

For the “same” trials, a similar rating pattern emerged for both groups, with 96% of responses corresponding to 1 (or “same”) and the remaining 4% were 2, or “similar.” Given these results, we will only address the “different” trials in the analysis that follows. In Table 4 we present the distribution of the rating scores from experiment 1:

Table 4. Table 4. *Percentage for each rating score on ‘different’ responses for target item trials (raw total in parentheses)*.

Figure 2 shows the distribution of the scores across the two groups:

Figure 2. *Distribution of ranking scores across Native Spanish and L2 Spanish listener groups*
Insert Figure 2 here

Figure 2 shows that for the ‘different’ stimuli, the Native Spanish speakers’ scores clustered around two modes: ‘2’ and ‘4’ while the L2 listeners were almost uniform in their rating of ‘5’. Because the data have non-normal distribution and involve rating scores, we used the Mann-Whitney U-test to determine if there are differences among the rating scores associated

[3] The issue that arose with the rhotics was with the native Spanish speakers. Specifically, the stimuli were not uniformly perceivable as either the trill or tap phoneme. Where the rhotic was judged as more tap-like in word initial position, a violation of Spanish phonotactics occurred (only the trill can occur in initial position). The native Spanish listeners commented that it sounded more like a ‘d’ onset than the desired trill.

with the two groups. The Mann-Whitney U test showed a significant difference between the means on the rating scores for the two groups: U= 41016; exact $p<0.001$, two-tailed.

We conducted a second analysis to determine if there were any differences in rating scores for the different types of target trials across the two groups. Again, because the data is not normally distributed, we used the non-parametric Friedman Test to investigate whether there was an effect for position of the allophone (onset vs. medial, CV.CV vs. V.CV). Extensive cross-linguistic research has shown that onset hardening is common in many disparate languages (Kenstowicz, 1994: Basque; Gordon, 1997: Estonian) and there is a general tendency in language to strengthen consonant articulations in initial position of elements found in the prosodic hierarchy (Cho, 2001; Fougeron, 1997). This may mean listeners are more attuned to the differences between the two palatal variants in initial position than in medial position. Given this, we might expect a higher proportion of "very different" (5) responses for the CV.CV items than for the medial target items and further predict that these differences will be greater for the native Spanish listeners than for the L2 Spanish listeners. The results show that indeed, the Native Spanish listeners are more sensitive to the variant in onset position than the L2 listeners [$\chi^2(4)=22.6$, $p<0.001$]. For medial position, there was also a significant difference between groups, although it was not as pronounced as for onset position [χ^2 $(4)=8.2$, $p<0.05$).

2.5 Discussion

The results from this experiment show that native Spanish listeners rate the "different" trials as more similar than the L2 Spanish listeners. This suggests that the same input is grouped into separate modes by the different listener groups, based upon perceived similarity. Specifically, the

Native Spanish listeners demonstrate two modes in their rating of the palatal trials, with 29% of listeners rating them as similar (with a value of '2') and 62% rating them as different (with a value of '4'). This result stands in contrast to that obtained from the L2 Spanish listeners, who rated the different trials almost uniformly (89%) with '5', or 'very different'. The fact that the Native Spanish listeners demonstrated two modes in their responses might be attributable to the gradiency of the palatal sounds in general and the position-dependent nature of their occurrence. We further observed significantly different rating scores from the native Spanish listeners when the palatal alternation occurred in word-initial position versus word-medial position. When the alternation occurs in word-medial position, native Spanish listeners split between perceiving the trials as "similar" (2) and "different" (4) (38.6% and 37.1% of responses, respectively). This finding suggests that native Spanish listeners perceive the alternation as more distinct in onset position than in medial position, which means that allophonic variants may be perceived differently across their distinct positions by native speakers of a language. The results support the hypothesis that L2 Spanish listeners can perceive the palatal alternation but do not necessarily perceive them as closely related and more importantly, their rating of how similar the two variants are is significantly different from the rating given by the Native Spanish listeners.

In experiment 2 we examine the same contrast, but using a different task. In an effort to determine if such language-specific effects carried down to lower-level perception, listeners carried out a speeded AX discrimination task. Research examining adult speech perception using rating and speeded AX discrimination has brought mixed results. While Boomershine et al. (2008) found that language-specific listening occurred in both the rating and speeded AX discrimination tasks, Johnson and Babel (2007; 2010) found that language-specific listening only occurred for longer response times (RTs).

3. Experiment 2: speeded AX discrimination task

3.1 Participants

The same 29 native Spanish and 30 L2 Spanish participants from experiment 1 participated in experiment 2. However, we had to discard the results from five native Spanish speaker participants because they informed the experimenter after finishing that they had confused the response buttons for many of their answers. Three L2 Spanish listener results were discarded because more than 50% of their responses were too slow (longer than 500ms) and four were discarded because they confused the response buttons (again, they informed the experimenter after the experiment was finished).This gave a total of 24 and 22 participants for each group. All experimental tasks were counterbalanced across participants and participants were granted a short break between tasks. Experiments 1 and 2 were never presented consecutively.

3.2 Stimuli

The target stimuli took the same form as that used for experiment 1. There were two important differences, however. First, we added an extra vowel, [e], to the trial sets, giving [a e o u] for the CV.CV trials. We used the consonants [p b ɾ r] and the clusters [bl t̪ɾ d̪ɾ kɾ kl] for the filler trials.[4]

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[4] [t̪ɾ d̪ɾ] were only used for “same” trials after submitting the tokens to evaluation by three native Spanish speakers after running the experiment (not part of the study group) who stated that these particular tokens were not clearly audible. Three of the native Spanish speaker participants

There were 144 trials in total: 32 targets (16 “same”/“different” for CV.CV and V.CV targets) and 112 fillers.

3.3 Procedure

The goal of this experiment was to test auditory-level responses with as little interference from higher-level categories as possible. Thus, the trial pairs were presented with a very short 100ms interstimulus interval (ISI) and a 500ms response deadline. Listeners were told they would hear a pair of invented words based on Spanish and they were to determine if the second member of the pair was the same or different from the first member. They were told to respond as quickly and accurately as possible by means of a button on a button box attached to the computer. The experiment was conducted using Superlab experimental software on a Mac computer. If no response was recorded, the program continued to the next trial. Every eight to ten trials a screen appeared reminding listeners that they were to respond as quickly as possible. If they exceeded the 500ms limit, a screen appeared telling them their response was too slow and that no answer was recorded. Listeners were provided with five practice trials before beginning the experiment. They received feedback on accuracy and reaction time for the practice trials.

3.4 Results

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commented on the fact that they were not sure if they were in fact hearing the voiced or voiceless occlusive.

Across the two groups, responses which exceeded the 500ms limit constituted 8.9% of the trials for the native Spanish listeners and 9.3% for the L2 Spanish group. These responses were discarded. We then divided the responses into same/different and subsequently correct/incorrect categories. For the "same" trials, the accuracy rate was 97.3% for the native Spanish listeners and 95.2% for the L2 Spanish listeners. We conducted a one-way ANOVA for group on the proportion of correct responses for the "same" trials and found no significant differences in accuracy rates (F (1, 732) = 0.81, $p > 0.05$). Subsequently we conducted a one-way ANOVA on LogRT latencies for the "same" trials and again found no significant differences between the two groups ($F(1, 732) = 1.02$, $p > 0.05$). Given that the objective of this experiment is to investigate how speeded discrimination affects perception of the palatal variants on the "different" trials, we did not include the response time and latencies for the "same" trials in further statistical analyses. For the "different" trials, the accuracy rates were 91% for the native Spanish listeners and 93% for the L2 Spanish listeners.

We analyzed the data using an ANOVA with LogRT as the dependent variable, group (native or L2 Spanish) and condition (onset fricative, medial fricative, onset affricate, medial affricate) as the factors. For the condition factor, the first member of the trial pair determined the condition for the trial. The results revealed a significant main effect for group ($F(1, 309) = 12.4$, $p = 0.001$, $\eta^2 = 0.038$). There was also a main effect for condition ($F(3, 657) = 14.9$, $p < 0.001$, $\eta^2=0.046$). There was an interaction between group and condition ($F(3, 657) = 6.7$, $p < 0.001$, $\eta^2 = 0.021$). In Figure 3 we show the LogRTs for each condition, separated by group.

Figure 3. *LogRT for speeded AX discrimination task across groups and conditions*.

Insert Figure 3 here

To more fully examine the interaction between condition and group, we conducted a series of independent *t*-tests on the means for each condition for each language group. For the native Spanish group, significant results emerged across all pairs (medial affricate-onset affricate: $t(155) = 2.52$, $p = 0.013$; medial fricative-onset fricative: $t(155) = 5.1$, $p < 0.000$; onset affricate-onset fricative: $t(155) = -2.24$, $p = 0.027$; medial affricate-medial fricative: $t(155) = 5.14$, $p < 0.001$). For the L2 Spanish listeners, significant differences emerged for the pair medial affricate-onset affricate ($t(154) = 3.22$, $p = 0.02$) and medial affricate-medial fricative ($t(154) = 4.24$, $p < 0.001$).

3.5 Discussion

The results from the speeded AX discrimination task support previous research (Johnson & Babel, 2007; 2010) demonstrating a language effect even in tasks that draw upon auditory representations. The Native Spanish speakers could distinguish between all pairs while the L2 learners could only distinguish between pairs that involved the medial affricate. For the Native Spanish speakers, an interaction emerged between position (onset/medial) and manner (affricate/fricative), suggesting the variants are close to complementary distribution for these listeners, in spite of the gradiency present in the linguistic input (but the experimental stimuli were binary, which may be the motive). For the L2 listeners, on the other hand, only the medial affricate was perceived as significantly distinct from the other input. These results are somewhat surprising, given that those obtained in experiment 1 where the Spanish listeners perceived the two variants as similar sounding while the learner group did not. We suggest that the L2 listeners may be using a language-specific encoding strategy when evaluating the stimuli. Babel and Johnson (2010) suggest a similar explanation for their finding of language-specific discrimination of fricatives, but only at longer response latencies, listeners appeared to use language-specific discrimination. The results obtained here appear to support this There was a significant main effect for group (shorter LogRTs for the Native Spanish listeners) which suggests that the L2 listeners may have been using a non-acoustic level of perception. Whether they were using English or Spanish as their baseline comparison is difficult to determine. One possible indication that they are not using Spanish is the finding that the medial affricate proved to be the most distinct when compared across pairs. Our results from experiment 1 showed that the *onset* position favoured the greatest degree of ‘different’ ratings for the Native Spanish speakers. It is also important to keep in mind that our stimuli were recorded by a native Spanish speaker and all experiment interaction occurred in Spanish. Our listeners were operating from Spanish when carrying out this task, which may also have affected their responses, limiting the pure acoustic nature of their response.

In experiment 1 we showed that native Spanish listeners perceive the palatal alternation differently from the L2 Spanish listeners and in experiment 2, we also showed evidence that language-specific effects may play a role even in low-level acoustic perception. These results suggest that the two groups are sensitive (albeit in different ways and to different degrees) to the presence of the palatal variant and furthermore, are sensitive to the positional nature of the restriction.

In experiment 3 we examine how the two listener groups use the palatal alternation in an artificial speech segmentation task. Given the results from experiment 1, which indicate that

Native Spanish speakers recognize the palatal variants as ‘similar’ (but not the same) and the results from experiment 2, which indicate that on a lower-level perceptual level they can nonetheless distinguish between them, we predict that the Native Spanish listeners will use the probabilistic information related to the distribution of the two variants in the segmentation of an artificial speech stream. Thus, we predict that the native Spanish speakers (NSS) exposed to an artificial language stream *with* the palatal alternation will be more successful at segmenting word forms than those exposed to an input stream *without* the alternation. However, this may not be the case for our L2 listeners. Experiment 1 showed that these listeners perceive the palatal variants as ‘very different’, which may mean that they are not aware of how these sounds are tightly linked to certain probabilistic distributions in the Spanish input, a fact further supported by the results from experiment 2 where language-specific discrimination was found to hold even on low-level acoustic tasks. If this holds, L2 Spanish listeners will rely upon transitional probabilities as their only cue to segmentation and the availability of the palatal variant as a cue to ‘word’ boundaries will not boost the segmentation accuracy for the L2 learners. They are predicted to be at chance for both input streams.

4. Experiment 3: artificial language segmentation task

In an artificial language segmentation task, listeners are exposed to input streams of concatenated syllables with different co-occurrence probabilities. Listeners begin to recognize as potential wordforms syllables that co-occur with greater frequency in the input; conversely, syllables that do not co-occur are not grouped together as possible wordforms. For example, if a listener has no knowledge of Spanish, but yet hears the word *casa* ‘house’ repeatedly in the speech stream surrounded by other words, she will eventually realize that the syllables *ca+sa* form a coherent word unit in Spanish. Typically, researchers manipulate the transitional probabilities between syllables to as potential word boundaries. In Experiment 3, we added an extra element to this typical artificial speech segmentation task and instead of having listeners rely solely upon the co-occurrence probabilities cross syllables when segmenting out possible wordforms, half of the participants were exposed to a speech stream with the palatal alternation present and the other half were exposed to a speech stream with no palatal alternation. Thus, half of our listeners had the additional cue of the palatal alternation to boost their segmentation accuracy, provided they were sensitive to the role it plays in indicating a probabilistic word boundary in Spanish. Specifically, half of our NSS and L1 English/L2 Spanish (L2 Spanish) listeners were randomly assigned to an artificial language stream called AltSpan (with the allophonic alternation) and the other half to NonaltSpan (without alternations). In AltSpan, the transitional probabilities (TPs) were boosted by the presence of the allophonic alternation while in NonaltSpan, only the fricative variant occurred and listeners had to rely on TPs alone. Following twelve minutes of exposure to the artificial language speech stream, each group carried out a forced choice lexical decision task in which they had to decide which member of a pair of words was a potential word from the language they heard.

4.1 Participants

The same participants took part in experiment 3 as in experiments 1 and 2 above.

4.2 Stimuli

Table 6 provides the six trisyllabic words that were concatenated to form the artificial speech stream. They took the following forms: ((C)CV.(C)CV.(C)CV). Of the six word forms, two had palatal sounds in initial position, two had palatal sounds in the third syllable and two had no palatal sounds at all. No palatal-initial syllables occurred in the medial syllable. In an artificial speech segmentation task, the ‘words’ are contrasted with ‘nonwords’ based upon the probability of their syllable co-occurrence. For example, if the listener hears the syllables [ɟʝa] + [pi] + [nu] consistently together in the input stream, they have a transitional probability (i.e., linear co-occurrence probability) of 1.0. On the other hand, if the listener hears the syllables [nu] + [fɾu] + [li], these syllables never co-occur and the probability drops to zero. Moreover, the probability between of co-occurrence between the different wordforms themselves was 0.167, that is, the wordforms were combined in such a way that they only had a 1/6 chance of occurring one after the other. All syllables respected the phonotactic patterns of Spanish. Table 6 presents the items used for experiment 3:

Table 5. *Test items for artificial language segmentation task*.

Insert Table 5 here

A native Mexican Spanish female speaker recorded each syllable in isolation and then in bisyllabic and in trisyllabic combinations. The dominant σ(ˈσσ) trochaic stress pattern found in Spanish was maintained. To verify that there were indeed differences between the stressed and unstressed syllables, we conducted independent t-tests on the pitch, intensity and duration of the vowels in the stressed vs. unstressed syllables[5]. Significant differences emerged in all cases ($p<0.05$), confirming that the stressed syllables were in fact phonetically distinct from the unstressed syllables. Since our goal was to have the artificial speech stream resemble real speech as closely as possible and also preserve the transitional information, we had to shift the stress to different syllables for the words not found in the speech stream as compared to the real words. Crucially, no target or non-target word had stressed palatal-initial syllables.

Some of the part-words did not occur in the speech stream, which meant that listeners could not rely upon transitional probabilities to recognize them. However, their status as ‘new words’ should lead to an advantage for the occurring words as potential lexical items heard in the input stream. To address possible effects for this within and between groups, we conducted a mixed ANOVA (part-word status X group). The results revealed no main effect for part-word status ([F 1, 5] = 1.02, p=.12) but did reveal an almost significant difference between groups ([F 1, 59] = 32.1, p=0.061). There was no part-word status group interaction observed. These results suggest that the presence of some of the part-words in the input stream did not give these items an advantage over the others.

For the target wordforms (high internal syllable co-occurrence probabilities) the average duration was 582ms. For the non-target words, the average duration was 577ms. The syllable with the affricate onset ([ɟʝ]) was 158ms long and the affricate itself was 39ms. The fricative-initial syllable was 146ms long and the fricative itself was 49ms. In Figure 4 we provide a spectrogram of the syllables with the target palatal segments:

[5] We averaged the values for the two unstressed syllables.

Figure 4. *Examples of stimuli used for experiment 3*

Insert Figure 4 here.

4.3 Procedure

Participants were told they were going to listen to a new variety of Spanish and they should simply listen to the speech stream as closely as possible. To avoid possible overanalysis of the input, participants were given a sheet of paper on which they were encouraged to draw or doodle. Participants wore headphones during presentation and testing. After the twelve-minute exposure time, participants carried out the forced choice test. They were told they would hear pairs of words and had to choose which one constituted an example of a possible word from the language they just heard. Reponses were indicated by means of pressing a button on a button box and participants were encouraged to guess where they were not sure. The stimuli were presented in pairs using a Macbook Pro computer running Superlab experimental software. All trials were randomized; half of the trials began with the word taken from the artificial language stream and half were part words consisting of syllables found in the target words.

4.4 Results

Figure 5 shows participants' performance as accuracy percentages, broken down by language group and condition.

Figure 5. *Mean accuracy rates across groups and conditions for ALL*

Insert Figure 5 here

Performance accuracy for each group exceeded chance (50%). Native Spanish speakers in the alternating condition averaged 76% correct (*SD* = 1.2) and the native Spanish speakers in the non-alternating condition averaged 68% correct (*SD* = 0.98). For the L2 Spanish group, accuracy reached 60% (*SD* = 0.6) for the alternating condition and 58% (*SD* = 0.44) for the non-alternating condition.

We carried out a two-way mixed ANOVA with group (Native Spanish vs. L2 Spanish) as the between-subjects variable and condition (Alternating vs. Non-Alternating) as the within-subjects variable. Accuracy on the forced choice task was the dependent variable. Results showed a main effect for group ($F(1, 58) = 28.1, p<0.001$). There was also a main effect for condition ($F(1, 58) = 12.3, p<0.001$) and an interaction between group and condition (($F(1, 55) = 9.1, p<0.001$). Given the interaction, we carried out a Tukey's HSD and found that for the Native Spanish group, there was a significant difference between the two conditions ($p<0.01$) while for the L2 group, there was no such difference.

These results suggest that the presence of the allophonic palatal cue to word onset leads to more accurate identification of words on the forced choice task for the native Spanish listeners. For the L2 listeners, this result did not reach significance, suggesting that the allophonic benefit was not as strong.

In order to isolate potential effects for the allophone onset, we examined accuracy rates for test items that began with a palatal allophone. We hypothesized that native Spanish speakers exposed to the alternation might have higher accuracy rates for the trials that included only palatal onset items (e.g., [ɟ͜ʝefɾuso] (word) ~ [jemupo] (nonword)). For the L2 listeners, we predicted no significant difference. Figure 6 shows participants' accuracy on test trials with palatal words only, broken down by language group and condition.

Figure 6. *Percentage correct for palatal words.*

Insert Figure 6 here

We subsequently carried out a one-tailed independent samples *t*-tests for each group on the palatal-initial accuracy rates, which revealed a significant difference in mean accuracy across the native Spanish speaker groups in the two different conditions ($t(27) = 6.64$, $p < 0.001$). For the L2 listeners, there was no significant difference between the two conditions.

As can be seen in Figure 6, there is greater variance for both native speakers and learners for the affricate-initial words in the alternating condition, as compared to the fricative-initial words in the non-alternating condition. This suggests that the learners may be moving towards a more native-like pattern of sensitivity to the variants.[6]

These findings support those presented above, confirming that the presence of a palatal affricate in word onset position leads to more successful segmentation of the artificial speech stream by native Spanish speakers. Again, consistent with the results presented previously, the L2 Spanish listeners do not benefit from the availability of this cue to word onsets. The L2 Spanish speakers did not show higher accuracy rates for the words exhibiting the palatal affricate segments.

[6] We thank an anonymous reviewer for pointing this out to us.

4.5 Discussion

In experiment 3, we showed that the extraction of word forms by native Spanish listeners benefits from the presence of the palatal allophonic cue to word onsets. This result is consistent with previous research showing that the TP-tracking mechanism in the input stream is rendered more powerful when combined with language-specific phonotactic information. The L2 Spanish listeners, on the other hand, did not benefit as fully from the presence of the affricate/stop onset.

In our artificial language segmentation task listeners had to track transitional probabilities present in the speech signal AND recognize language-specific allophonic alternations that coincided with the TPs in indicating word boundaries. Thus, language-specific allophonic information reinforced the transitional probabilities, which can be likened to the real-world task of segmenting the speech stream where phonotactic cues and TPs reliably coincide. Nonetheless, only the native Spanish speaker group was helped by the presence of the language-specific allophonic cue to word onsets. This suggests that while listeners do not necessarily have to use both TPs and the allophonic cue to segment the speech stream, only the native Spanish speakers benefitted from the mutually reinforcing nature of these two cues to segmentation. The L2 listeners do not appear to do so and instead rely primarily upon the TPs. In order to benefit from the presence of the palatal alternation in the segmentation task, L2 listeners must be able to represent this knowledge abstractly and use it to segment the artificial speech stream in an on-line fashion. This suggests that the L2 listeners may not be aware of the distributional information linked to the affricate variant in (probabilistically) indicating word onset in Spanish.

Alternatively, they may indeed be aware of the alternation but not in all contexts or under all task conditions. To further explore this, we carried out experiment 4.

5. Experiment 4: word spotting task using phonotactics

The goal of experiment 4 is to investigate how the presence of a specific variant of the palatal alternation affects the recognition of words combined with initial context syllables. we adapted a methodology used by Weber and Cutler (2006, for German and English) in which listeners were exposed to sequences that were either phonotactically highly probably or, conversely, highly improbable in Spanish, conditioned upon the final sound in the context syllable and the palatal variant occurring in initial position of the embedded word (e.g., GLEN+*llave* ‘key’). Improbable sequences violate expectations regarding the allophone in onset position. In Spanish, the affricate version of the palatal variant (or even the palatal occlusive [ɟ]) occurs after nasal consonants and the lateral [l]. This may reflect a similar phonetically-grounded motivation as that observed with the [b d̪ g] ~ [β̞ ð̞ ɣ̞] whereby the [d̪] is not realized as its approximant counterpart following the lateral, as in *aldea* ‘village’ [ald̪ea], *[alð̞ea]). In the current study, the nasal and lateral-final context-syllables probabilistically condition the more consonant-like version [ɟʝ] of the palatal variant in the following word. Vowel-final context syllables, on the other hand, favour the fricative in the onset.

Such phonotactic restrictions are not inviolable in Spanish (as compared to, say, the well-known inviolable constraint against [s]+obstruent clusters in onset position *[sku̯e.la] vs. [es.ku̯e.la]) in Spanish. Instead, the substitution of an unexpected allophone variant is predicted to disrupt expectations regarding the initial palatal allophone and lead to longer latencies, at least in the case of the native Spanish speakers. Nonetheless, the recognition of the word itself should not be impeded.

5.1 Participants

The same participants who took part in experiments 1 and 2 also took part in this experiment. The results from one native Spanish and two L2 Spanish listeners were eliminated because they neglected to register the moment they recognized the embedded word and only wrote it on their sheet of paper.

5.2 Stimuli

All items were recorded via a Sennheiser microphone directly onto a PC computer. The speaker was a female native Mexican Spanish speaker, instructed to avoid any clear syllable boundaries in her productions.

Participants were exposed to 60 nonwords with real Spanish words embedded in them. The twelve target words had a palatal target sound in onset position. All words were taken from a corpus of the 5000 most common words in Spanish (Davies, 2005) or from the first-year Spanish textbook used by the L1 English/L2 Spanish participants. The 60 filler items were among the 1000 most frequent Spanish words, according to Davies (2005) and, moreover, were taught as vocabulary items in the first eight chapters of the Spanish language textbook used in the university language program followed by the L2 participants. As Weber and Cutler (2006) note, word frequency counts may not reflect the experience of L1 and L2 listeners in the same way; however, when the manipulation of interest is carried out within items, this problem is alleviated.

While all five vowels can occur in open syllables in Spanish, coronal consonants are much more frequent in coda position compared to consonants at other places of articulation (with exceptions mostly found in borrowings and learned Latinisms). Yet this tendency is not categorical, as a reviewer notes that labial and velar coda segments are possible; the reviewer lists: *cá*[p.s]*ula* 'capsule,' *ca*[p.t̪]*ar* 'to capture,' *a*[k.s]*ión* 'action,' *é*[k.s]*ito* 'success,' *a*[k.t̪]*o* 'act,' *corre*[k.t̪]*o* 'correct,' *pa*[k.t̪]*ar* 'to agree on,' *a*[ɣ.n]*óstico* 'agnostic,' *i*[ɣ.n]*ición* 'ignition,' *i*[ɣ.n]*ominia* 'disgrace,' *i*[ɣ.n]*orar* 'to ignore' and *ma*[ɣ.n]*animidad* 'magnanimity.' (To complete the paradigm, voiced labial codas such as *a*[β.s]*urdo* 'absurd' might be included.) [7] Within words, in non-velarizing dialects, target nasals in coda position assimilate place of articulation to the following consonant.

[7] However, we would like to point out that the list does not constitute a counterexample to the claims that (a) codas *tend* to be coronal and (b) most exceptions are found in borrowings, as each example above is itself a learned word borrowed from Classical Latin. This is evinced by the maintenance of consonant clusters that were reduced or otherwise modified (via sound change) in the patrimonial lexicon of Spanish: CAPSA [p.s] > *caja* [x] 'box,' CAPTĀRE [p.t̪] > *catar* 'to look at,' LACTEM [k.t̪] > *leche* [tʃ] 'milk,' SIGNU [g.n] > *seña* [ɲ] 'sign'. Furthermore, such words are subject to synchronic simplification, often undergoing vocalization (*a*[u̯.s]*urdo* < *a*[β.s]*urdo*, *corre*[i̯.t̪]*o* < *corre*[k.t̪]*o*; see Piñeros, 2001) or elision (*a*[s]*ión* < *a*[k.s]*ión*; Pharies, 2007) in casual speech, demonstrating their vulnerability.

In terms of nasal consonants, most varieties of Spanish exhibit neutralization whereby nasals in word-final position are realized as either the alveolar [n] or the velar [ŋ]. Within words, in non-velarizing dialects target nasals in coda position assimilate place of articulation to the following consonant. We did not use any syllables with final [s] because of the high tendency for that segment to undergo either deletion or aspiration across Spanish dialects. In contrast to the nasal segments, [s] can be elided completely in certain varieties of Spanish.

In Spanish, the palatal segment in word onset or medial position can be represented orthographically the letter *y* (*yema* 'eggyolk') or, alternatively, by *ll* (*llama* 'call'). Another way this sound is represented orthographically in Spanish is by means of the combination *hiV*, as in *hielo* 'ice' or *hierro* 'iron'. Three of our test items exhibited this particular orthographic combination. According to Hualde (2005), Spanish speakers typically pronounce the first two orthographic patterns with the affricate when it occurs in the correct phonotactic context (after a pause or after a lateral/nasal segment) but when the orthographic combination *hiV* occurs at the beginning of a word, speakers typically produce it more like the palatal fricative or even a glide, or attributable to orthographic effects that manifest phonetically. For the present experiment, this meant that the three test items with *hiV* in initial position could potentially be recognized faster in the non-alternating condition because the palatal segment tends to be pronounced as a fricative rather than the affricate. In Figure 7 we present examples of the stimuli used for experiment 4:

Figure 7. *Examples of stimuli used for experiment 4*

Insert Figure 7 here

We selected six context syllable templates (initial syllables) that were subsequently combined with the target words and fillers. Table 6 presents the initial context syllables used with the target words.

Table 6. *Context syllables and lexical items for word spotting task*.

Insert Table 6 here

We selected bisyllabic trochees, which, when combined with the context syllables, gave the trisyllabic form σ(ˈσσ). Thus, in addition to whatever phonotactic and allophonic cues are available in the input, listeners could also take advantage of primary stress cues. In Spanish, 75 to 80% of words follow the trochaic stress pattern (Harris, 1983; Quilis, 1984); specifically, penultimate (medial) stress accounts for 73.52% of trisyllabic words (LEXESP database: Sebastián-Gallés, Martí, Carreiras & Cueto, 2000). In sum, the trochaic/penultimate stress pattern comprises nearly three-fourths of the Spanish lexicon. For English, Clopper (2002) analyzed tokens from the Hoosier Mental Lexicon (Luce & Pisoni, 1998) and found that three-syllable words in English exhibit primary stress most frequently on either the first or second syllable. However, when the type frequency for both accentual patterns is divided by the token frequency, second syllable stress is more common. Thus, based upon the distribution of stress patterns across the English lexicon, native speakers expect to encounter primary stress most often on the second syllable of three-syllable words, followed by the first syllable. Of the twelve context syllables that occur with the target items, four are vowel-final, four are lateral-final and four are nasal-final.

To avoid possible priming effects, we presented each word only once to the listeners, which was necessary given the relatively small number of possible and appropriate target items. While most word spotting experiments ask participants to make lexical decisions on the items they hear with the target items being real words and a proportion of the fillers being nonwords, in the present experiment we changed the procedure slightly. Instead of asking listeners to make lexical decisions, they were instructed to listen closely and press the corresponding button when they detected a word and then write it down on a sheet of paper. Because of the limited vocabulary size exhibited by our listeners, we did not use nonword distractors for our task. Our participants only heard real words and were asked to identify them by writing them down on a sheet of paper.

In this experiment we are testing linear phonotactic knowledge as well as lexical recognition in favourable vs. unfavourable contexts. If listeners recognize the phonotactic information regarding the expected context for each palatal variant and use this to activate their expectation regarding the palatal segment in the onset of the following word, there should be a significant difference between the alternating vs. non-alternating conditions. While this is not a typical word-spotting experiment, the methodology nonetheless allows us to test the effect for linear phonotactic context and the knowledge listeners have of these expected contextual variants. The predictability of the context syllable in terms of length and boundary location does not interfere with the conclusion that phonotactic knowledge is involved in spotting the words.

We also conducted a small-scale control experiment to guarantee that our stimuli could be identified correctly without the context syllables. Following Weber and Cutler (2006), we presented three native Spanish and ten L1 English/L2 Spanish listeners with twenty-two items, ten of which were taken from the experimental fillers plus the twelve experimental items themselves. For the experimental items, we excised the context syllables and presented half with the fricative onset and half with the stop/affricate onset. The fillers were presented with their context syllables. Listeners were asked to press a button whenever they heard a Spanish word and subsequently write it down on a sheet of paper. The native Spanish speakers reached 100% accuracy (22/22, 12/12 on the target items) and a paired sample *t*-test revealed no significant differences among participants between target items and fillers with the context syllable ($t(11) = 0.82$, $p > 0.05$) in terms of response latencies; nor were there significant differences between the fricative onset and stop/affricate onset RTs, either ($t(11) = 0.71$, $p > 0.05$). The L1 English/L2 Spanish listeners reached 90% accuracy (average 20.2/22, 10.8/12 on target items) on the excised target items and 100% correct on the filler items. A paired sample *t*-test revealed significant differences between the excised target items and the embedded filler items, with the latter latencies being longer ($t(11) = 2.31$, $p < 0.05$). Given these results on the control task, we can safely assume that both the native Spanish and the L1 English/L2 Spanish groups can identify the target items with their context syllables excised and can identify the filler items embedded in their context syllables.

5.3 Procedure

The stimuli were presented in pairs using a Macbook Pro computer via Superlab experimental software. All trials were randomized.

Participants were told they would hear nonwords in Spanish in which real words were embedded. They were to listen and as soon as they detected the real word, they were to press the corresponding button on the button box. They then had to write the real word down on a sheet of paper provided by the experimenter. Participants had four seconds to respond, after which the following item was presented. They were given four practice items that did not occur among the filler or experimental trials.

5.4 Results

We predicted that the different boundaries between the context syllable and target words would have an effect on how quickly these words are recognized by listeners. Furthermore, we predicted that there would be an interaction between boundary and group. Specifically, following the results in the artificial speech segmentation task, native Spanish speakers exposed to target items with the stop/affricate variant in onset position should have shorter latencies than those exposed to target items with the fricative variant. For the L1 English/L2 Spanish group, on the other hand, we do not expect to find any significant differences in latencies or accuracy rates across the two types of input. In Table 7 we present the means and standard deviations for each group across each condition.

Table 7 RT (LogRT) means and SD for word spotting task conditions.

Insert Table 7 here

Within each group, no significant differences in accuracy were observed for the word spotting task. We carried out a three-way mixed ANOVA on the latencies, with group and condition as the between-subjects factors and context syllable as the within-subjects factor.

There was a main effect for group (the Native Spanish speakers were faster overall than the L2 group, [F(1 , 55)= 19.2, p<0.001]. There was also a main effect for condition [F(1,55)= 10.2, p<0.01), due to the faster reaction times for both groups on the Alternating condition. Finally, there was also a main effect for context syllable, [F(1, 55)=18.3, p<0.001]. There was also a significant group, condition and context-syllable interaction [F(1,55)=12.8, p<0.01]. In Figure 8 we present graphs of the results:

Figure 8. *Results from experiment 4.*

Insert figure 8 here.

Given that our hypothesis was related to group differences across the two conditions, we followed up the significant three-way interaction with a series of *t*-tests on the condition factor for each group. For the native Spanish listeners, there was no significant difference for the vowel boundary condition ($t(27) = 0.780$, $p = 0.445$) but there was a significant difference for the lateral boundary ($t(27) = 3.137$, $p = 0.002$) and the nasal boundary conditions ($t(27) = 4.96$, $p < 0.001$). For the L2 Spanish group, there was a significant difference for the vowel boundary condition ($t(27) = 2.187$, $p = 0.04$) and the lateral ($t(27) = 2.56$, $p = 0.012$) and nasal boundary conditions ($t(27) = 2.16$, $p = 0.009$).

5.5 Discussion

The question addressed by experiment 4 was whether the type of context syllable boundary segment would lead listeners to expect a certain palatal variant in the onset of the lexical item and if so, whether this effect would hold across the two groups of listeners. The significant interaction between context syllable and group suggests that our overall prediction held. There is a significant advantage for native Spanish speakers on a word spotting task when the embedded word occurs in a phonotactically expected context. However, the results also show that the L2 Spanish listeners benefit from the presence of the palatal variant on this task.

After comparing within-group differences across the two conditions, we found that only the L2 listeners demonstrated significantly faster reaction times in the vowel-final context syllable condition. The Native Spanish speaker group did not, following our initial prediction. One way of accounting for this may be that the native Spanish speakers are exposed to a great deal of variability in terms of the palatal variant and thus are more accepting of either the fricative or the affricate in word onset, following a vowel. In other words, they may not have stored specific linear probabilities beyond some sort of occlusive palatal segment in initial position. The significant difference observed in the L2 learners' reaction times suggests that they may have a particular expectation regarding palatals in word onsets, that is, the affricate segment. Another possibility is simply that the affricate provides more robust acoustic cues to word onset and thus facilitated word recognition more than the fricative variant, a cue which they rely upon to a greater extent than the Native Spanish listeners.

In this experiment, we examined the effect of linear phonotactic context on word spotting, using the same variant examined in the three previous experiments. While our methodology was different from that used by Weber and Cutler (2006), our results are generally consistent with theirs. Specifically, Weber and Cutler found that phonotactically-expected word onsets were recognized faster than those which violated the phonotactics of the L2 (and L1 in Weber & Cutler). In our case, the word spotting stimuli did not violate English phonotactics (given that the closest English categories are not predictably distributed) but did require knowledge of probabilistic nature of the palatal variants in Spanish. Experiment 4 also examined how linear phonotactic knowledge interacts with allophonic, or conditioned, sound change. In the Weber and Cutler study, the phonotactically expected word onsets were not variants of a less ‘probable’ sound, as in the present case. Thus, our results add to those of Weber and Cutler by showing that learners are also sensitive to which variant is more likely in a particular linear phonotactic context.

The finding that L2 listeners are able to use this information to spot words more quickly in favourable contexts suggests that adult second language learners are sensitive to linear phonotactic restrictions in their second language and in particular, L2 Spanish learners are aware of the distributional properties of the palatal variants as they relate to strictly linear phonotactic relations. However, when these same listeners were exposed to the artificial speech stream in experiment 3, they did not benefit from this knowledge. As well, experiments 1 and 2 suggested that the L2 learner group categorized and discriminated the palatal segments very differently from the Native Spanish speakers while in experiment 4, the learner results aligned with those of the Native speakers. Thus, we are left with the issue of how best to account for the differences across the distinct tasks and furthermore, how to account for these differences given that we are examining the L2 perception of target language positional variants. We turn to this in the discussion section.

6. General discussion

In this study we presented four experiments that examined how Native Spanish and L2 Spanish listeners perceive and use the palatal consonant variants across a series of speech tasks. In experiment 1, we showed that when asked to rate stimuli that contrasted only in the palatal variant, the two language groups judged the palatal variants' similarity in very different ways. Specifically, the Native Spanish speakers rated the stimuli as less 'distinct' than the L2 learners. These results suggest that native language sound categories (both contrastive and non-contrastive) and the distributional information linked to each sound modulates the way listeners judge the similarity of sounds. In experiment 2, listeners listened to pairs of non-words and had to judge whether they were the same or different, under strict time pressure. Again, the results point towards a native-language effect even at 'low-level' phonetic perception (see Babel and Johnson, 2010 for a similar result).

The results from experiment 3 suggest that L2 Spanish learners do not benefit from the presence of the palatal alternation when segmenting an input stream. It is possible that L2 listeners are either not aware of the distributional information linked to the palatal alternation in the input or are potentially aware of it but unable to draw upon it when completing the task. When considered in the light of the word-spotting task results, the latter explanation seems to be the most likely: L2 listeners ARE sensitive to the presence of the stop/affricate allophone in onset position when it occurs at the start of a real word in a phonotactically-likely context. This suggests that a) the functional role of native-language speech categories will influence the perception of second language sounds and b) task effects play a role in the degree to which these effects play out. Together, these experiments provide a mixed picture in terms of how Spanish L2 listeners 'use' the palatal allophone alternation to carry out tasks in their second language.

In order to account for these results, we must explain how the same participants benefit from the palatal affricate variant to spot words in phonotactically likely contexts but do not benefit when the palatal affricate is combined with TPs in the artificial speech stream. Native Spanish listeners, on the other hand, perform equally well on both tasks when the allophone alternation is present.

7. Conclusion

The general conclusion emerging from this study is the finding that the interplay between language-specific relations of contrast and task effects is complex. The question that naturally falls out from this is what prevents learners from accessing information consistently. We suggest that an attentional filter may modulate L2 performance on speech tasks, resulting in effects such as those observed here. Typically, attentional models address the use of cues in the input and whether the L2 listener can perceive cues that are objectively available through a gradual process of cue re-weighting (Holt & Lotto, 2006). In the case of distributionally-conditioned variants such as those examined here, learners must not only perceive the cues but also link each to its respective context (Shea & Curtin, 2010; 2011). Whether this is best accounted for by a model allowing contextual effects to be stored in representations or , alternatively, accounted for by means of some sort of variance-eliminating mechanism lies beyond the scope of this paper. By examining the role of task effects in L2 speech perception we demonstrated that such an task-based attentional filter operates as well. One way of accounting for this may be that learner representations are veridical in the sense of storing information present in the signal, but this information may not be consistently available across all task conditions, unlike in the case of native speakers (see Shea & Curtin, 2010; 2011 for similar conclusions). We do not discount the need for abstract phonological representations (Pierrehumbert, 2002; Weber & Cutler, 2004) as well, given that the results obtained in experiment 3 on the artificial speech segmentation task suggest that the L2 learners may not yet have developed such representations which they can apply to new input streams. Native listeners are clearly sensitive to phonetic details in the signal but they are also capable of generalizing to new word forms and using abstract information to resolve ambiguities in the signal.

In speech perception research it is now accepted that distributional learning drives speech category learning. Nonetheless, it is not yet well understood how attention interacts with the information learners ultimately access when carrying out speech tasks. In this study we tested the same target sounds across different task conditions and showed that L2 learners can use distributional information associated with the palatal variants in certain tasks but do not seem to benefit from it when performing others.

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Table 1. *Biographical information*.

Group	Age	Years studying foreign language	Age started studying
Native Spanish (*n*=29)	M=21.3 (0.8)	M=4.1 (1.1)	M=10.1
L1 English/ L2 Spanish (*n*=30)	M=20.2 (1.2)	M=4.8 (1.2)	M=14.5

Table 2. *Acoustic description of stimuli*

SEGMENT POSITION	DURATION DIFFERENCE *(MEAN)*	INTENSITY RATIO *(SEGMENT: SEGMENT)*	TOKEN DURATION *(MEAN)*	FRICATION DURATION DIFFERENCE *(AFFRICATE)*	BURST INTENSITY DIFFERENCE *(AFFRICATE)*
Within segments/ across position					
fricative [**ʝ**oma]/[o**ʝ**a]	5ms	0.97 (SD=.025)	463ms (SD=11)		
affricate [ɟʝuma]/[uɟʝa]	4.7ms	.98	460.2ms (SD=9.8)	3.33ms	2dB
Between segments/ same position					
onset [**ʝ**oma]/[ɟʝoma]	22ms	1.18	8ms		
medial [o**ʝ**a]/[oɟʝa]	4ms	1.23	4ms		

Table 3. *AX rating task trials*.

	CV.CV				V.CV			
	same		different		same		different	
	[j]ama*	[j]ama	[j]ama	[ɟʝ]ama	a[j]a	a[j]a	a[j]a	a[ɟʝ]a
Target	[j]oma	[j]oma	[j]oma	[ɟʝ]oma	o[j]a*	o[j]a	o[j]a	o[ɟʝ]a
pairs	[ɟʝ]ama	[ɟʝ]ama	[j]uma	[ɟʝ]uma	o[ɟʝ]a	o[ɟʝ]a	u[j]a	u[ɟʝ]a
	[ɟʝ]uma	[ɟʝ]uma	[ɟʝ]ama	[j]ama	u[ɟʝ]a	u[ɟʝ]a	a[ɟʝ]a	a[j]a
			[ɟʝ]oma	[j]oma			o[ɟʝ]a	o[j]a
			[ɟʝ]uma	[j]uma			u[ɟʝ]a	u[j]a
	[s]ama	[s]ama	[l]ama	[s]ama	o[s]a*	o[s]a	a[l]a*	a[s]a
Filler	[s]oma	[s]oma	[l]oma	[s]oma	o[l]a*	o[l]a	o[l]a	o[s]a
pairs	[l]oma*	[l]oma	[l]oma	[r]oma	u[l]a	u[l]a	o[l]a	o[r]a*
	[r]ama	[r]ama	[l]uma	[r]uma	a[r]a	a[r]a	u[l]a	u[r]a
			[r]ama	[s]ama			a[r]a	a[s]a
			[r]uma	[s]uma*			u[r]a	u[s]a*

* = possible Spanish word

Table 4. *Percentage for each rating score on 'different' responses for target item trials (raw total in parentheses).*

	Score (% of total 'different' trials for group)										
Group	**1 *(same)***		**2**		**3**		**4**		**5 *(very different)***		Mean (*SD*)
NSS *n*=696 (raw number)	2% (15)		29% (201)		1.6% (13)		62% (431)		6% (41)		3.42 (1.48)
	CV.CV	V.CV	CV.CV	V.CV	CV.CV	V.CV	CV.CV	V.CV	CV.CV	V.CV	
n=348 (%response for trial type)	1% (7)	1% (8)	11% (78)	18% (124)	0.7% (7)	0.9% (6)	35% (249)	26% (182)	1% (7)	5% (28)	
L2 Span *n*=720 (raw number)	1.7% (12)		1.25% (9)		1.8% (13)		8.1% (58)		87% (628)		4.78 (0.705)
	CV.CV	V.CV	CV.CV	V.CV	CV.CV	V.CV	CV.CV	V.CV	CV.CV	V.CV	
n=360 (% response for trial type)	0.8% (6)	0.8% (6)	0.5% (4)	0.5% (5)	0.8% (6)	0.9% (7)	3.1% (23)	4.7% (35)	40% (288)	47% (340)	

Table 5. *Test items for artificial language segmentation task.*

			Target words			
Alt	[ɟʝa.pi.nu]	[ɟʝe.fɾu.so]	[mu.pi.ja]	[mi.fɾa.je]	[li.su.bɾo]	[lu.bɾe.ni]
NonAlt	[ja.pi.nu]	[je.fɾu.so]	[mu.pi.ja]	[mi.fɾa.je]	[li.su.bɾo]	[lu.bɾe.ni]
			Part words			
Alt	[so.bɾo.ɟʝa]	[bɾe.ni.ɟʝe]	[ɟʝa.fɾa.lu]	[ɟʝe.mu.po]	[pi.nu.mi]	[fɾu.so.li]
NonAlt	[so.bɾo.ja]	[bɾe.ni.je]	[ja.fɾa.lu]	[je.mu.po]	[pi.nu.mi]	[fɾu.so.li]

Table 6. *Context syllables and lexical items for word spotting task.*

<table>
<tr><th>Context syllable</th><th>ll-</th><th>Context syllable</th><th>hie-</th><th>Context syllable</th><th>y-</th></tr>
<tr><td rowspan="2">glen-</td><td rowspan="2">llave
‘key’</td><td rowspan="5">ol-</td><td rowspan="5">hierro
‘steel’</td><td rowspan="16">prel-</td><td rowspan="16">yema
‘yolk’</td></tr>
<tr></tr>
<tr><td rowspan="2">kro-</td><td rowspan="2">llego
‘arrive’</td></tr>
<tr></tr>
<tr><td rowspan="2">lon-</td><td rowspan="2">llora
‘cry’</td></tr>
<tr><td rowspan="6">grel-</td><td rowspan="6">hierba
‘grass’</td></tr>
<tr><td rowspan="2">on-</td><td rowspan="2">llanta
‘tire’</td></tr>
<tr></tr>
<tr><td rowspan="2">san-</td><td rowspan="2">llenas
‘fill’</td></tr>
<tr></tr>
<tr><td rowspan="2">so-</td><td rowspan="2">llama
‘call’</td></tr>
<tr><td rowspan="5">pral-</td><td rowspan="5">hielo
‘ice’</td></tr>
<tr><td rowspan="2">bra-</td><td rowspan="2">lleva
‘carry’</td></tr>
<tr></tr>
<tr><td rowspan="2">se-</td><td rowspan="2">lluvia
‘rain’</td></tr>
<tr></tr>
</table>

Table 7. Log*RT means (ms) and SD for word spotting task conditions*.

	Context syllable		
	(C)C**<u>V</u>**- (*se*-***lluvia***)	VC[l]/[n]- (C)CV[l]/[n]- *(ol-**hierro**)* *(on-**llanta**)*	Overall mean
Native Spanish			
Alternating	2.83	2.77	2.79
Non-Alternating	2.88	2.94	2.93
L2 Spanish			
Alternating	2.86	2.94	2.92
Non-Alternating	2.94	3.1	3.02