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Durational Cues to Resyllabification in Spanish

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ABSTRACT: Word-final consonants in Spanish are post-lexically resyllabified when followed by an onsetless syllable, e.g. *venden aves* ('they sell birds') is traditionally syllabified as *ven.de.na.ves* and is considered homophonous with *vende naves* ('he sells ships'). This study analyzes such two-word minimal pairs inserted in prosodically equivalent sentences read from a list and provides measurements of the acoustic duration of resyllabified /s/, /n/, and /l/, and of their flanking vowels. A mixed-model analysis showed that, when resyllabified as derived onsets, all three consonants pattern together and show a shorter duration (*venden aves*) in comparison with canonical onsets (*vende naves*). This is consistent with the coda position that they occupy in the lexical representation, given the weak nature of codas. However, vowel duration varies according to consonant identity. These results are discussed in terms of the articulatory gestures making up the target consonants and allow to interpret that the resyllabified consonant actually becomes the onset of the following syllable. Therefore, we offer converging evidence of resyllabified consonants acting both as codas and onsets, and consequently we propose they can be analyzed as ambisyllabic.

Keywords: Spanish, resyllabification, duration, articulatory gestures, ambisyllabicity

RESUMEN: *Pistas acústicas para la resilabificación en español.* En español, las consonantes finales de palabra se resilabean posléxicamente cuando van seguidas de una sílaba sin ataque, de forma que *venden aves* normalmente se resilabea como *ven.de.na.ves* y es considerada homófona con *vende naves*. Este estudio analiza pares mínimos como estos, compuestos de dos palabras insertadas en oraciones prosódicamente equivalentes leídas de una lista, y proporciona medidas de la duración acústica de /s/, /n/ y /l/, así como de sus vocales adyacentes. Un análisis de regresión mediante modelos mixtos mostró que, cuando se resilabean y actúan como ataques derivados, las tres consonantes se comportan de la misma manera y muestran una menor duración (*venden aves*) en comparación con los ataques canónicos (*vende naves*), lo cual es coherente con la posición de coda que ocupan en la representación léxica, dada la naturaleza débil de las codas. En cambio, la duración de las vocales adyacentes varía en función de la identidad consonántica. Estos resultados se discuten en términos de los gestos articulatorios que conforman las consonantes analizadas y permiten interpretar que los ataques derivados realmente se convierten en el ataque de la sílaba siguiente. Por ello, ofrecemos pruebas que sugieren que las consonantes resilabeadas actúan como codas y como ataques y, en consecuencia, proponemos que puedan analizarse como ambisilábicas.

Palabras clave: español, resilabeo, duración, gestos articulatorios, ambisilabicidad

1. INTRODUCTION

Spanish exhibits a post-lexical reorganization of syllable structure in a phenomenon known as resyllabification, which is characterized by the realization of a word-final consonant as the onset of the following word, so that an utterance such as *mis amigos* ('my friends') is syllabified as *mi.sa.mi.gos*. This process is subject to dialectal variation, ranging from dialects where the insertion of a glottal stop before a word-initial vowel prevents this phenomenon from occurring (e.g. Paraguayan Spanish, Trawick and Michnowicz, 2019) to others where only certain consonants have been reported to undergo resyllabification (e.g. Ecuadorian dialects, Robinson, 2012). In the case of Castilian Spanish, resyllabification has been traditionally considered to apply regardless of the identity of the consonant (Navarro Tomás, 1996 [1918], §§ 4, 154).

Another type of dialectal variation is related to the application order of resyllabification with respect to other allophonic rules. Obstruents in coda position typically undergo aspiration in many Spanish dialects and, thus, are realized as [h]. In some of these dialects, aspiration applies before resyllabification: for example, in Caribbean Spanish and Rio Negro Argentinian Spanish, an utterance such as *dos alas* ('two wings') surfaces as [do.ha.lah] (Kaisse, 1999). In contrast, the variety of Buenos Aires applies resyllabification first and, therefore, bleeds aspiration, so that the aforementioned utterance *dos alas* rather surfaces as [do.sa.lah] (Kaisse, 1999).

Examples such as the latter from dialects applying bleeding order reveal that word-final /s/ undoubtedly becomes syllable onset after resyllabification. A similar interpretation is supported by the Spanish tap /ɾ/, which presents several allophones in coda—[ɾ], [r], [ɹ], or [ɾ̪] (Blecua, 2001)—but when resyllabified it surfaces as [ɾ], the typical onset allophone.

Resyllabified codas (hereafter derived onsets) and word-initial onsets (hereafter canonical onsets) are considered to show no differences in their phonetic detail, i.e. they are held to be homophones (e.g. Hualde, 2005). Contrary to this view, several studies have reported subphonemic differences between derived onsets and canonical onsets in the case of /s/. As a result, derived onsets have been claimed to be distinguishable in their phonetic detail not only from canonical onsets but also from canonical codas, thus forming a third separate category (Hualde and Prieto, 2014; Strycharczuk and Kohlberger, 2016). On the one hand, the study conducted by Hualde and Prieto for the alveolar fricative /s/ yielded different results for the duration of the consonant in word-initial and word-final positions. More precisely, they found shorter target consonants when realized as derived onsets /VC#V/ than when realized as either canonical onsets /V#CV/ or as word-medial onsets /V.CV/, although no differences were observed between canonical onsets and word-medial onsets. The researchers, who analyzed the realization of /s/ from spontaneous speech elicited through a map task, also obtained the same results for Catalan, with the only difference that in this case /s/ also presented a significantly different duration in all post hoc comparisons.

On the other hand, a similar study was conducted by Strycharczuk and Kohlberger (2016), who analyzed the production of resyllabified /s/ in Castilian Spanish using speech samples elicited in a more controlled environment in order to avoid the undesired effects potentially associated to prosody and speech rate. As the results previously obtained by Hualde and Prieto, the realization of the target consonant was found to be shorter when resyllabified. The prosodic positions compared in this study for /s/ included canonical onsets (V#sV), canonical codas (Vs#C), derived onsets (Vs#V), word-medial onsets (V.sV), word-medial codas (Vs.C), and fake geminates (Vs#sV), and the results showed significant durational differences along the following structures: Vs.C < Vs#C < Vs#V < V.sV < V#sV < Vs#sV. The finding that derived onsets were longer than canonical codas but shorter than canonical onsets was also complemented with durational differences for the preceding vowel segments, i.e. the vowels preceding derived onsets and canonical onsets were longer than the vowels preceding codas (word-final and word-medial codas), although no such difference was found between vowels preceding derived onsets and those appearing before canonical onsets. Thus, the results obtained in both studies point to a three-way distinction in the phonetic realization of /s/, with derived onsets being consistently shorter than canonical onsets but longer than canonical codas, i.e. Vs#C < Vs#V < V#sV.

Similar results for differences in duration between derived onsets and canonical onsets have also been reported for other languages, e.g. for English (Lehiste, 1960; Smith and Hawkins, 2012; Tao et al., 2018; Turk and Shattuck-Hufnagel, 2000), for French (Fougeron et al., 2003; Shoemaker, 2009, 2014; Spinelli et al., 2003), and for Dutch (Quené, 1992; Shatzman and McQueen, 2006). In English, for example, the classical study conducted by Lehiste (1960) addressed the perceptual exploitation of temporal (among other) cues signaling the misalignment of word and syllable boundaries. Using minimal pairs differing in the lexical affiliation of the target consonant (*seem able* vs. *see Mabel*), she reported that the correct discrimination of the member of the pair that participants had just perceived consistently relied on the shorter duration attested for derived onsets. However, the different acoustic measurements conducted on recordings of three different speakers also revealed that each segment had other cues that were salient enough to have also possibly driven the listeners' perception.

In the case of French, the role of duration has also been studied in its potential for disambiguating minimal pairs in *liaison* contexts (Spinelli et al., 2003). Spinelli and her colleagues reported that consonants in *liaison* contexts —e.g. *dernier oignon*— were significantly shorter than their corresponding canonical onsets in cases such as *dernier rognon* and *demi rognon*, with no durational difference existing between the latter two.

Furthermore, in a study for Dutch, Quené (1992) studied some acoustic properties of twelve consonants in resyllabification contexts, e.g. *diep in* ('deep in') vs. *die pin* ('that pin'). As in the previously mentioned studies, his measurements showed a consistently shorter duration of the derived onsets when compared to canonical onsets.

The findings reported in the aforementioned studies offer evidence suggestive of a consistent difference in duration between derived onsets and canonical onsets. The present study aims at replicating the results reported for Castilian Spanish by Hualde and Prieto (2014) and Strycharczuk and Kohlberger (2016), which point to a durational difference for resyllabified /s/ with respect to canonical /s/. Furthermore, our intention is also to investigate whether such differences between derived onsets and canonical onsets can be extended to two other consonants such as /n/ and /l/, since so far, no results have been reported for these two consonants in this variety of Spanish.

2. METHODS

2.1. Participants and speech material

Nineteen native speakers of Spanish (4 males, 15 females, M_{Age} = 24.3, SD = 8.8), recruited among students of the Complutense University of Madrid, took part in the study. They did not receive any reward for their participation, and none of them was aware of the purpose of the investigation. Participants were monolingual speakers with no relevant differences in their Castilian Spanish dialect, except for 2 subjects, who were bilingual speakers of Catalan, although their Spanish was not different from the standard Castilian variety (see Appendix A1 for details).

The speech material was made up of paired sentences, each with a different lexical affiliation of the target consonant. Although the two-word sequences where the target consonant occurred were identical, the sentences themselves did not form minimal pairs, e.g. *Probablemente* MARCOS ALUDA *a Paco para despistar* ('Probably Marcos alluded to Paco to mislead you') vs. *Finalmente* MARCO SALUDA *a Lorena desde el tren* ('Finally Marco greets Lorena from the train'). Furthermore, the prosodic structure was similar between both members of each pair of sentences regarding the strength of the prosodic boundary between the two words forming the minimal pair. The stimuli included 8 pairs of sentences for /s/, 7 for /n/, and 4 for /l/ (see Appendix A2 for details). For every participant 2 repetitions of each uttered sentence were chosen, i.e., those sentences containing a disambiguating pause were rejected, which made up a total of 600 uttered sentences for the target consonant /s/, 524 for /n/, and 300 for /l/, which added up to 1424 utterances.

2.2. Procedure

Speakers were recorded uttering each member of the paired sentences separately in one of two recording sessions, which took place 3 weeks apart from each other so that they did not read both sentences belonging to a pair in the same session. In each session participants were presented with a total of 55 sentences to read out, which included 35 filler sentences next to the 20 stimuli containing the 3 target consonants. Before the recording, participants were allowed to get familiar with the speech material, and it was made sure that they understood all the words in the sentences presented to them. In addition, a trial in which they practiced with some of the sentences was used to provide them with instructions in order to prevent them from producing unnecessary pauses between words, i.e. they were asked to read out each sentence in a continuous manner, so that their speech production was connected. If they made a mistake while recording, they were encouraged to correct themselves by repeating the entire sentence. Besides, 2 repetitions of each sentence were recorded in the same session. The acoustic data were collected at a sampling rate of 44.1 kHz in Praat (Boersma and Weenink, 2018) by means of an AKG C3000 condenser microphone placed at about 30 cm in front of the speakers and connected to a Roland Rubix24 Audio Interface.

2.3. Data segmentation

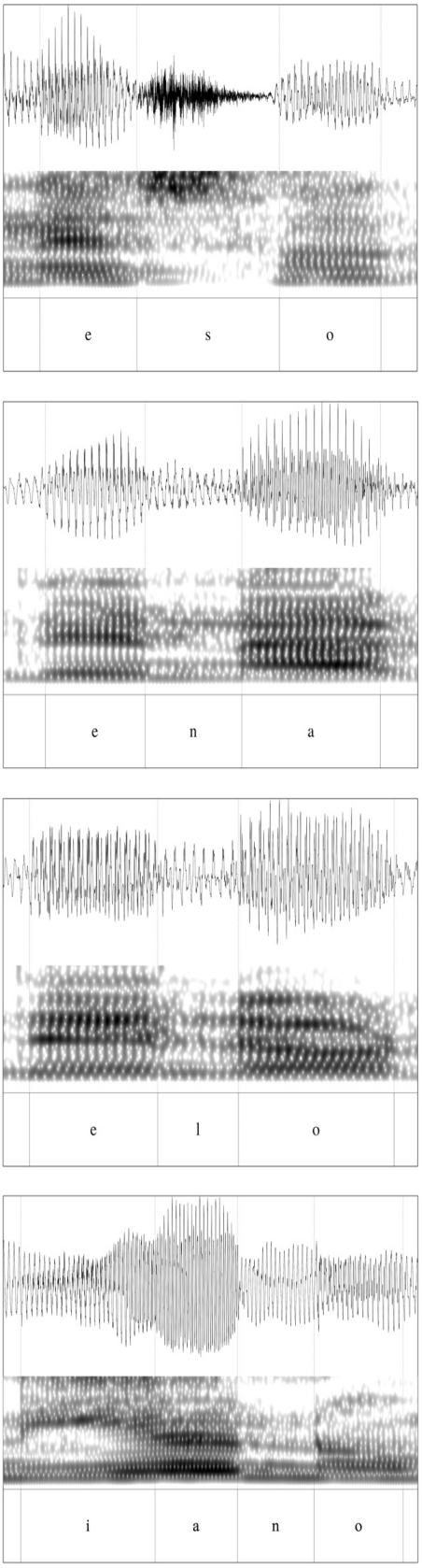
The segmentation of the acoustic data was manually conducted in Praat for the two repetitions of each sentence or for the only repetition of the sentence that was available in certain cases. The target consonants were segmented together with their flanking vowels according to the following criteria. The onset of /s/ was defined as the onset of frication noise appearing in the region of 3-5 kHz and higher, as done by Strycharczuk and Kohlberger (2016); while the offset was made to coincide with the appearance of the second formant belonging to the following vowel. For the target consonants /n/ and /l/, which occurred intervocalically, it was both the visible change in intensity and the change in the formant structure respect to the preceding and following vowels which determined the criteria for the segmentation. The onset of V1 was established according to the following criteria: the beginning of F2 when the vowel occurred after a stop or a fricative; the change in intensity after a tap, a trill, or a nasal; both the change in intensity and in the formant structure after a spirant; and finally, after another vowel, the boundary was set considering both the change in formant structure together with the first cycle of rising intensity after a visible decrease in the waveform. The boundary between V2 and the following segment was defined along similar criteria depending on its manner of articulation; in the case of stops or fricatives, the boundary was set when silence or noise, respectively, appeared in the region of 3-5 kHz (Figure 1).

2.4. Measurements and statistical analyses

By means of a Praat script, the duration of the three target consonants, as well as that of the preceding vowel (V1) and of the following vowel (V2), was measured based on the segmentation detailed above.

In order to statistically analyze our acoustic data, different linear mixed-effects regression models were separately fitted for each consonant using the *lme4* (Bates et al., 2015) package on R (R Core Team, 2021). The acoustic

Figure 1: Example of segmentations.



measurements conducted on the data were independently modeled with the categorical variable of condition —i.e. derived onset and canonical onset— as a fixed effect. Random effects were declared for speakers and paired items, since the study was designed with each individual sentence being paired with a prosodically equivalent one in order to control for any confounding variable that might have affected the speakers' production. This allowed to compare the derived onset condition within each pair of sentences with its canonical onset counterpart, both having the same context and characteristics. In addition, the variance-covariance matrix was fully declared as suggested by Barr et al. (2013), thus including intercepts for both random effects as well as a random slope for condition in by-subject random effects.

In order to assess whether bilingual participants presented any differences with respect to monolingual speakers, we followed Strycharczuk and Kohlberger (2016) and added Bilingual as an additional fixed predictor and its interaction with Condition. Since the effect of Bilingual and its interaction was not significant in any case, we decided to keep these participants in our analyses and did not include these variables in the models reported in the Results section. The dataset analyzed for this study and the R code can be found in https://osf.io/zbems/

3. RESULTS

Our results showed that the duration of the target consonant /s/ was significantly shorter for derived onsets when compared to canonical onsets, with a difference of 6.8 ms (SE = 1.4, t = –4.86, p < .001) (Table 1, Figure 1; see Table 2 for descriptive values).

Table 1: Summary of the fixed effects for target consonant /s/, /n/, and /l/ as predicted by Condition, i.e. canonical onset vs. derived onset. Only significant effects are reported.

Acoustic measurement	β (SE)	95% CI	t	p
Duration of /s/				
Canonical	97.5 (4.8)	88.2, 106.8		
Derived	–6.8 (1.4)	–9.6, –4.1	–4.86	<.001
Duration of V1				
Canonical	77.8 (4.7)	68.6, 87.0		
Derived	–3.0 (1.0)	–4.9, –1.1	–3.03	.003
Duration of V2				
Canonical	61.6 (3.7)	54.3, 68.9	16.60	
Derived	+3.0 (1.2)	0.7, 5.3	2.59	.018
Duration of /n/				
Canonical	53.1 (2.6)	48.1, 58.1		
Derived	–2.9 (1.2)	–5.3, –0.5	–2.36	.029
Duration of V2				
Canonical	76.3 (3.8)	68.9, 83.7		
Derived	+4.1 (1.0)	2.2, 6.1	4.14	<.001
Duration of /l/				
Canonical	63.7 (2.5)	58.8, 68.5		
Derived	–5.0 (1.0)	–7.0, –2.9	–4.81	<.001

A similar yet slightly more reduced difference in consonant duration was observed for /n/, with derived onsets being 2.9 ms shorter than canonical onsets (*SE* = 1.2, *t* = –2.36, *p* = .029). In the case of /l/, the same durational effect for the syllabic affiliation of the consonant was observed, and derived onsets proved to be 5.0 ms shorter than canonical onsets (*SE* = 1.0, *t* = –4.81, *p*. < .001). The duration of contextual vowels was also affected by the lexical affiliation of the target consonant. When /s/ was produced as a derived onset, V1 was 3.0 ms shorter than its non-resyllabified counterpart (*SE* = 1.0, *t* = −3.03, *p* = .002), while V2 was 3.0 ms longer (*SE* = 1.2, *t* = 2.59, *p* = .018). When /n/ was a derived onset, only V2 was affected, with an increase in duration of 4.1 ms (*SE* = 1.0, *t* = 4.14, *p* < .001). Conversely, no differences were observed for the vowels surrounding /l/.

4. DISCUSSION

Nineteen speakers of Castilian Spanish were recorded producing sentences within which the lexical affiliation of a target consonant—either /s/, /n/, or /l/—formed a two-word minimal pair with another sentence recorded in a different session, with both sentences offering a similar prosodic structure for the two-word minimal pair.

4.1. Consonant duration

The duration of the three target consonants, as well as that of their two flanking vowels, was analyzed on a total of 1424 uttered sentences. Our results replicated previous findings and confirmed that consonant duration is a consistent cue to resyllabification, i.e. in resyllabified contexts, derived onsets are produced with a shorter duration

Figure 2: Durational differences for all three target consonants and their surrounding vowels (CI at 95%).

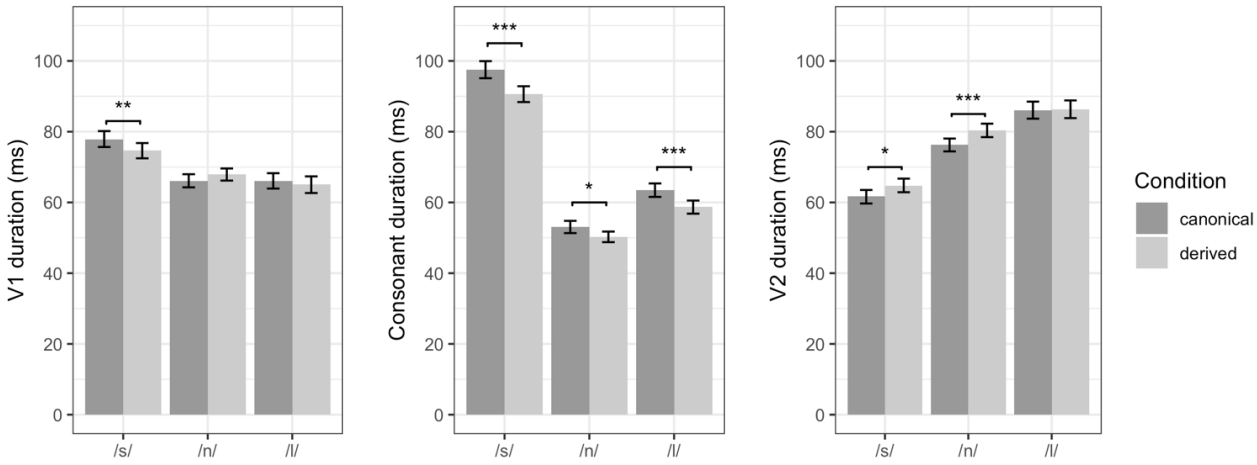


Table 2: Mean (SD) values for duration in ms.

		Canonical	Derived
/s/			
	V1	77.8 (20.1)	74.7 (18.2)
	C	97.6 (21.6)	90.6 (19.5)
	V2	61.7 (16.7)	64.7 (16.6)
/n/			
	V1	66.0 (14.5)	67.9 (14.4)
	C	53.1 (14.4)	50.2 (12.4)
	V2	76.3 (15.0)	80.3 (15.8)
/l/			
	V1	66.1 (14.1)	65.1 (14.6)
	C	63.5 (12.0)	58.7 (12.0)
	V2	86.1 (15.0)	86.4 (15.8)

than canonical onsets. This subphonemic difference was not only observed for /s/—as had been firstly reported by Hualde and Prieto (2014) and later by Strycharczuk and Kohlberger (2016)—but also for two other consonants in Castilian Spanish such as /n/ and /l/.

Acoustically, it has been pointed out that derived onset /s/ presents a duration intermediate between canonical codas and canonical onsets (Strycharczuk and Kohlberger, 2016), which suggests that it may constitute an intermediate phonological category. The fact that the acoustic duration of derived onsets was found to be systematically shorter than their canonical counterparts in our results is in line with the theoretical assumption that at least one acoustic cue exists that unifies the behavior of any segment—whatever its identity—for the sheer reason of being resyllabified. In this sense, regardless of the structural interpretation that resyllabified segments may be given, they constitute one phonological object and, as such, they are expected to have some phonetic behavior in common. More precisely, considering the prosodic nature of this phonological object, such a common cue is very likely to be suprasegmental. This finds support in our results, where the duration of the target consonant was affected by the derived condition independently of the consonant identity, especially since consonants originally associated to a coda position in their lexical forms are expected to be realized with a shorter duration than canonical onsets due to the weak nature of codas.

In our results, the difference between derived onsets and canonical onsets was larger for /s/—6.8 ms—than for the other target consonants. In contrast to the results obtained for /s/, the difference between derived onsets and canonical onsets for /n/ was 2.9 ms, while the difference of target consonant /l/—i.e. 5.0 ms—came closer to the results obtained for /s/. These temporal differences, albeit small, might potentially serve as a cue for the segmentation of continuous speech, although this should be further investigated with perceptual experiments.

Such temporal reduction of derived onsets with respect to canonical onsets makes it possible to consider that derived onsets present coda properties. As has been widely shown, gestures in coda position are in antiphase relation, which is inherently more unstable, and this fact renders coda segments shorter than their onset counterparts (Browman and Goldstein, 1992, 1995; Goldstein et al., 2006, p. 229). Another piece of evidence is offered by Byrd et al. (2009), who observed that the articulatory gestures of /n/ are synchronous as canonical onsets, but follow a sequential order when as derived onsets, as happens in coda position.

The evidence presented thus far shows that these consonants retain coda properties as expected from their lexical affiliation, and this might entail that resyllabification has not taken place. Admittedly, we cannot compare our data with canonical codas, since we did not include them in our design. However, we can provide evidence supporting that these consonants present onset properties, which allows to interpret that a post-lexical reorganization of syllable structure has actually occurred. In the case of Castilian Spanish, Strycharczuk and Kohlberger (2016) report a three-way distinction between /Vs#C/, /Vs#V/, and /V#sV/, where derived onsets display intermediate properties with respect to the other two. Besides, some aspiration dialects show [s] instead of [h] for /s/ in resyllabification contexts, and this bleeding order between resyllabification and aspiration is interpreted to show that this /s/ becomes syllable onset after resyllabification (Kaisse, 1999).

An additional argument finds support in the production of Spanish tap /ɾ/, which is made up of two tongue gestures, one with the body of the tongue and one with the tip, as shown by Proctor (2009) for a wide variety of Spanish dialects. Moreover, in Castilian Spanish, when this phoneme appears in a resyllabification context, it never surfaces as [r], [ɹ], or [r̝]—which are some of the possible coda allophones—but only as the typical onset allophone [ɾ] (Blecua, 2001), which can be interpreted as the tongue-tip gesture being coordinated in phase with the following vowel.

Given these facts attested for [s] and [ɾ], we may invoke a parsimony principle and suppose that other Castilian Spanish consonants also undergo resyllabification when followed by vowel-initial words, although this would be no more than an extrapolation based on theoretical grounds. Based on our own data, in section 4.2 we suggest that the duration of flanking vowels may be interpreted as additional evidence of combined coda and onset properties also in the case of resyllabified /l/.

Besides, there are data of other languages that suggest that this could be a common phenomenon. For example, in an EMMA study for Korean, the labial gesture of derived onset /m/ was in-phase coordinated with the following vowel, i.e. it presented the same pattern of articulation as canonical onset /m/ (Cho et al., 2014).

This converging evidence of the maintenance of coda properties and the manifestation of onset properties points to an ambisyllabic nature of derived onsets, which results from their specific configuration of articulatory gestures. In the lexical form, the gestures of the consonant are coordinated to the previous vowel by virtue of an antiphase relation, as is typical of codas (Browman and Goldstein, 1992). Besides, when the consonant occurs before a vowel-initial word, there is a post-lexical restructuring that establishes an additional link with the following vowel. As a matter of fact, derived onsets can be interpreted as constituting an intermediate category between canonical codas and canonical onsets. This is suggested by the intermediate temporal duration observed for derived onsets (Strycharczuk and Kohlberger, 2016) and by their articulatory gestures, which are simultaneously phased to its two flanking vowels (Gick, 2003)[1].

[1]An ambisyllabic account of derived onset /s/ may be at odds with the evidence mentioned in the introduction section for the bleeding order of rules that are applied in certain dialects. In this sense, if /s/ were arguably still a coda, it should surface after resyllabification as the aspirated allophone typically occurring in coda position, even if the aspiration rule is applied at a later stage. The only reason one might provide for it not to surface as the aspirated allophone would be that the aspiration rule actually does not apply to segments in coda position but rather to segments occurring not in onset position. Such a rule

An anonymous reviewer has suggested that the durational differences between derived and canonical onsets might be due to other reasons. For example, canonical onsets might be longer by virtue of the initial strengthening affecting consonants that are word-initial at the lexical level. While it is true that this effect on consonantal duration could be explained invoking other reasons, we believe that the ambisyllabic account has the advantage of also explaining the changes in duration of the flanking vowels, as will be discussed in the next section.

4.2. Duration of contextual vowels

The duration of the surrounding vowels was also affected by the process of resyllabification in our results, but in a different manner depending on the identity of the consonant. On the one hand, a shorter duration of V1 and a longer duration of V2 were observed when in the presence of a derived onset /s/. On the other hand, V1 duration was not significantly affected by condition in the case of /n/ and /l/, and V2 was longer in the case of derived onset /n/ but not significantly different in the case of derived onset /l/.

These results are in contrast with the absence of significantly different durations of contextual vowels in the case of /s/ in the study by Strycharczuk and Kohlberger. In this sense, we wonder whether methodological differences in the production of the speech material might be responsible for such a contradiction. They included a single carrier sentence that was systematically repeated by participants, who might have emphasized or somehow highlighted the target sequence. Furthermore, it was probably easier for participants to realize the purpose of the researchers' study, whereas the difference in our results might have arisen due to the naïve condition of our subjects.

Our interpretation of the durational differences for the contextual vowels found in this study is based on the different articulatory gestures involved in the production of each target consonant. More precisely, the fricative /s/ is achieved by a critical narrowing made with the tongue tip at the region of the alveolar ridge. The nasal /n/ also consists of a tongue-tip gesture, although in this case it requires a full contact with the alveolar ridge; and additionally, this is accompanied by a velum lowering gesture[2]. In its turn, Spanish /l/ has been described as being made up of a tongue-tip gesture (with an alveolar contact and a lateral approximation) plus a tongue-tip body gesture realized as a pharyngeal approximation (Proctor, 2009)[3].

If we suppose that the tongue-tip gesture of derived onset /s/ is simultaneously linked in antiphase to V1 and in phase to V2, a compromise must be met between these two opposing demands. In other words, the beginning of derived onsets cannot be fully aligned with the beginning of V2, as would be expected of a canonical onset by virtue of their in-phase coupling, but neither does it coincide with the halfpoint of V1 gestures, as would correspond to a coda: it rather lies in the middle of those points (Figure 3). This could explain an earlier timing of the consonant gesture in comparison with that of canonical onsets, thus resulting in a larger overlap with V1—which is therefore shortened—and a lesser overlap with V2—which is therefore lengthened.

Similarly for /n/, the ambisyllabic character of the lingual gesture might explain the lengthening observed for V2. However, a similar shortening of V1 as the one for /s/ was not found for /n/ (nor for /l/). A possible reason for this could be related to the specific constriction degree involved in the realization of these consonants. For example, while /s/ and /n/ are clearly a continuant and an interrupted consonant, respectively, /l/ has been described to behave differently according to the continuant/interrupted value depending on the language (Mielke, 2005). In Spanish, the evidence suggests that /l/ behaves as an interrupted consonant at least from the phonological point of view, as can be concluded from the fact that it patterns together with other interrupted consonants in the allophonic rule that predicts a voiced stop (instead of a spirant) after a homorganic interrupted (Lahoz-Bengoechea, 2015, § 4.3.1; Lozano, 2000 [1978], p. 325).

Thus, nasals and laterals require a full articulatory contact, similarly to stops and differently from fricatives. It is known that, as compared to fricatives, stops show a higher velocity in the articulatory gesture (Löfqvist and Gracco, 1997), and perhaps it could be interpreted that the same applies to nasals and laterals.

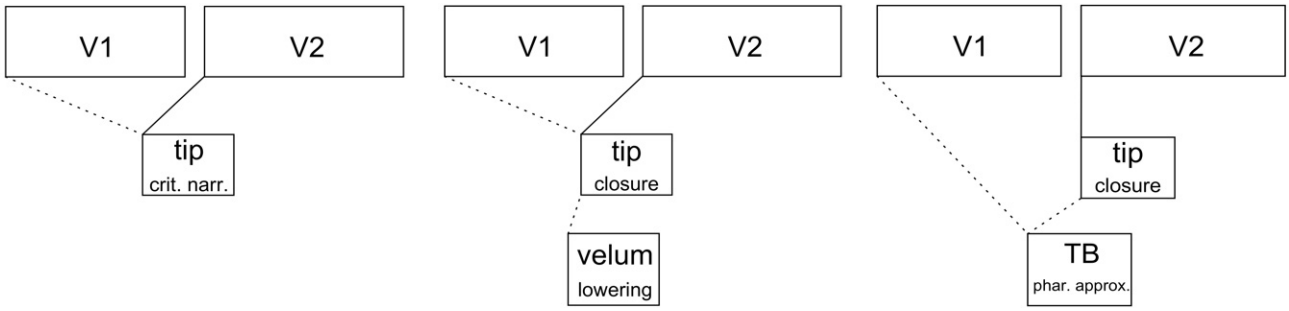
The faster achievement of the target and the subsequent shorter duration of the gesture might possibly explain why, even if the beginning of that gesture is slightly anticipated with respect to the canonical condition, the consonant barely overlaps with the preceding vowel, and consequently the duration of V1 is not significantly affected by the derived condition. In any case, such a possible difference in

formulation is certainly unusual, but although both formulations are generally equivalent, this difference would explain the absence of the aspirated allophone in this case. Given that aspiration is an instance of weakening, its occurrence might be prevented by the greater stability provided by the onset in-phase coordination, even if the segment is concurrently engaged in a coda relation.

[2] In Spanish, the velum gesture does not seem to be directly coupled with V1, as suggested by data on nasalization. According to the studies conducted by Solé (1992, 1995), the temporal extent of nasalization remains fairly constant and does not vary proportionally with changes in vowel duration. Solé argues that nasalization in Spanish is simply a consequence of phonetic mechanisms and not of a phonologically specified relation between the vowel and the velum gesture.

[3] When in coda, the tongue-body gesture is timed earlier than that of the tongue-tip. One might think that this anticipation should make derived onset /l/ acquire some of the properties described for dark [ɫ], which is against most acoustic descriptions of Spanish /l/ (e.g. Recasens, 2012). Traditionally, [ɫ] has been understood as the consequence of an earlier timing of the tongue-body retraction relative to the tongue-tip gesture (Sproat and Fujimura, 1993). However, further evidence suggests that darkness is not actually rendered by an anticipation of the tongue-body gesture but rather depends on the degree of gestural constriction achieved between the tongue-body and the pharynx (Narayanan et al., 1997; Proctor, 2009). Thus, an antiphase coupling between the tongue-body and the tongue-tip does not contradict what is generally known about the acoustic properties of coda /l/ in Spanish.

Figure 3: Graphs showing the coordination of the articulatory gestures proposed for the derived onsets analyzed in this study (/s/ on the left, /n/ in the middle, /l/ on the right). Box sizes are not intended to iconically reflect acoustic duration. Solid lines represent in-phase coordination and dashed lines correspond to antiphase coordination. Abbreviations: crit. narr. (critical narrowing), TB (tongue-body), phar. approx. (pharyngeal approximation).



the articulatory velocity needs to be further studied using ultrasound or articulographic measures. Nonetheless, this behavior might be based on another underlying property affecting both consonants.

Finally, in the case of coda /l/ the consonant is typically made up of a tongue-body gesture (antiphased to V1) and a tongue-tip gesture (antiphased to the tongue-body gesture), which has been also confirmed for Spanish (Proctor, 2009). By virtue of resyllabificationand based on an ambisyllabic account, the tongue-tip gesture would acquire an additional link to V2 (in phase). This predicts a simultaneous beginning of both the tongue-tip and the V2 gestures and a V2 similar in duration to the one following a canonical onset.

In summary, our results suggest, firstly, that consonants in the derived onset condition retain coda properties as shown by their shorter duration with respect to canonical onsets. Secondly, the onset status of resyllabified consonants can be attested by comparing the different durational behavior of the contextual vowels depending on the consonant identity. More precisely, both an ambisyllabic and a canonical coda interpretation would predict a shorter duration of V1 and a longer duration of V2 with respect to canonical onsets, and this is exactly what was observed for /s/. In both accounts, the antiphase coordination with V1 results in a gestural overlap with this preceding segment, which therefore undergoes a temporal reduction. In the case of V2, the greatest overlap would occur with a canonical onset, while an ambisyllabic consonant would show an intermediate overlap due to the opposing demands of the coordination with both flanking vowels, and a canonical coda would not show any overlap at all. Consequently, both the ambisyllabic and the canonical coda accounts would predict a shorter duration of V2 than that of canonical onsets. By the same token, the observed increase in duration of V2 for resyllabified /n/ could be equally explained by both accounts just mentioned (Figure 4).

Our results for /l/, however, allow to disambiguate between those two possible interpretations, inasmuch as a canonical coda—as just described—would predict a longer V2 than in the case of canonical onsets, whereas the in-phase link invoked by the ambisyllabic analysis does predict a V2 similar in duration to that of canonical onsets, precisely as can be seen in our results. (Figure 4).

4.3. Ambisyllabic representation of derived onsets

The possibility of an ambisyllabic representation for derived onsets was considered by Strycharczuk and Kohlberger (2016) in the discussion of their results, although they objected that two different phonological objects such as derived onsets and geminate consonants cannot have the same representation, and they reserved ambisyllabicity for the latter, especially since geminates have traditionally been analyzed in autosegmental terms as occupying two prosodic slots, i.e. coda and onset. On the contrary, we would like to suggest that geminates can be given a different phonological representation, while derived onsets may actually be analyzed as ambisyllabic. Therefore, in the following we offer evidence against an ambisyllabic representation of geminates, which in our view cannot constitute one single segment simultaneously associated to both the coda and the onset positions.

The first piece of evidence pointing to a possible reinterpretation of geminates can be found in Cypriot Greek, where it has been observed that f_0 minima are approximately aligned with an intermediate point of the geminate consonant, so that the observed pitch rise takes place in its second half (Tserdanelis and Arvaniti, 2001). A similar tonal alignment has also been reported for concatenated geminates in English (Gao and Xu, 2010). As a result, it is possible to infer that geminates are not one single but longer consonant, since otherwise tonal events would be expected to align rather with its beginning, as they do in the case of singletons.

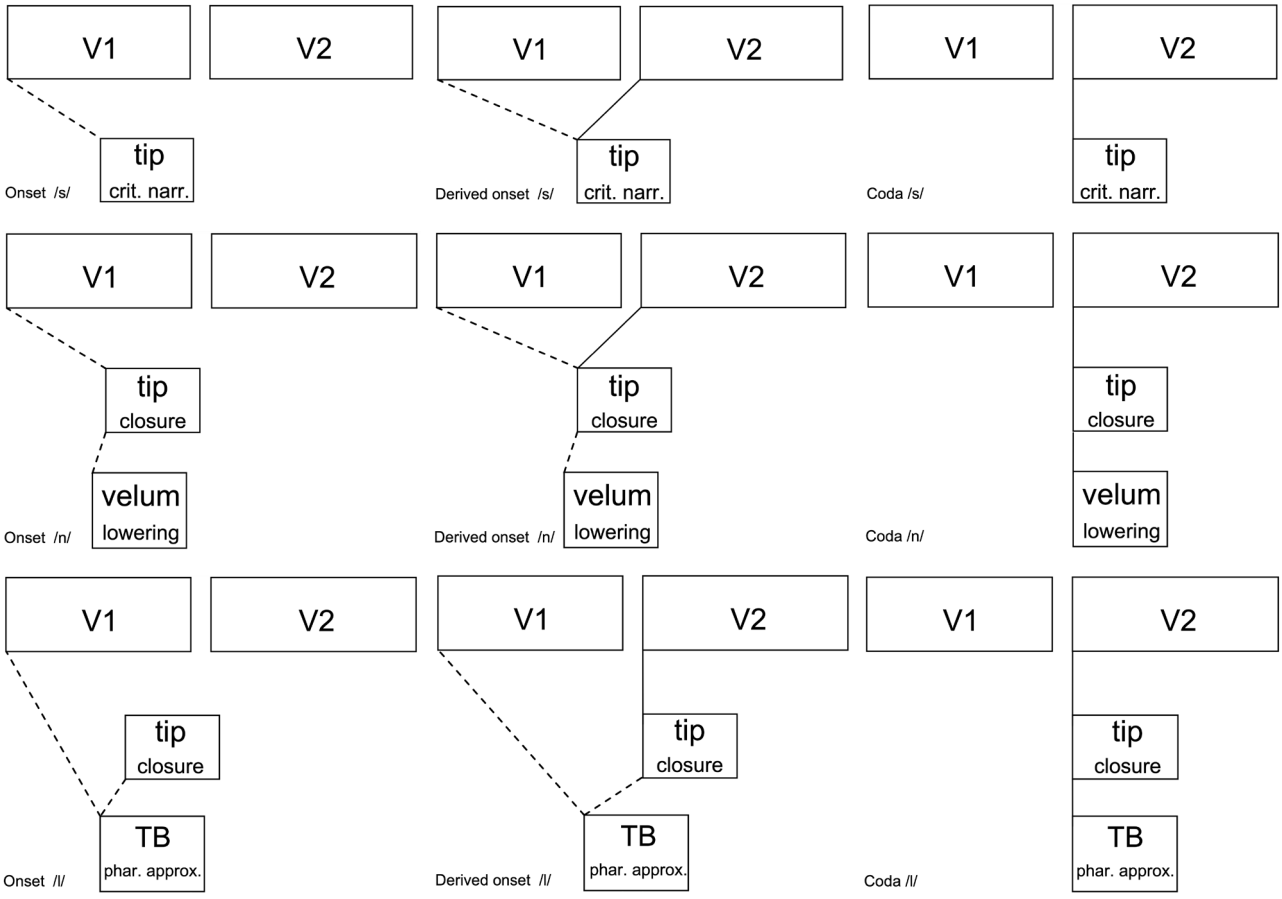
In support of this view, we draw on the framework of articulatory phonology, which initially posited the notion of the articulatory gesture as the basic unit of phonological events (Browman and Goldstein, 1992), as previously mentioned. The model of articulatory phonology was later enriched with two more types of gestures: on the one hand, gestures aligned with the boundaries of prosodic constituents affecting the dynamics of articulation—i.e. π-gestures, (Byrd and Saltzman, 2003)—and on the other hand, gestures targeting a H(igh) tone and L(ow) tone—i.e. tonal gestures (Gao, 2008). The dynamics and overlap of these three different types of gestures are determined by their coordination—whether in phase or antiphase—in the gestural score of articulation, where the beginning of each gesture serves as the anchor point in the control of coordination (see Hall, 2017 for a review).

Specifically, the beginning of tonal gestures is coordinated in phase with the beginning of the gestures belonging to the nuclear vowel. Onset consonants are also coupled in phase with the nuclear vowel, so the onset is estimated to begin roughly in alignment with the tonal gesture. Since Cypriot Greek shows a pitch turning point at about the middle of the geminate consonant, this point should be interpreted as the articulatory beginning of the vowel and also as the beginning of the onset. Crucially, the geminate cannot be considered one single but longer articulatory gesture—if that were the case, the vowel would start halfway through the consonant, in what could be seen as a sort of antiphase relation. As just said, anchor points for coordination are necessarily located at the beginning of gestures. Since this is the case, and the onset is required to be in phase with the vowel, the f_0 turning point reveals the start of a new gesture, leading to the conclusion that geminates must be represented as a sequence of two consonants.

Secondly, our interpretation of geminates as sequences of two identical segments is supported by Tilsen's description of the acquisition of phonological patterns in speech development (Tilsen, 2016). In his account, Tilsen points out that geminate consonants arise by reselecting the same motor plan as that of the previously realized segment. In the first stage of development, children have not learned yet how to reselect action units and therefore produce geminates as short as singletons. On a subsequent stage, they can reselect the motor plan, but rely solely on external feedback to know that the first instance of that plan is completed prior to reselecting it. In other words, not until they hear the acoustic consequences of the first unit or feel the appropriate degree of muscular tension do they proceed to reselect the motor plan. This gives rise to an abnormally long geminate production. Finally at a later stage of the development, children learn to anticipate the consequences of their articulation, and this anticipation—called internalized feedback—, allows them to reselect units in advance, so that the greater overlap between consecutive actions yields geminates as long as expected.

Consequently, this view allows to posit a similar account for lexical geminates and for geminates concatenated across word boundaries, both consisting of a sequence of two consonants. The difference is that lexical geminates are produced by reselecting one unit of motor planning, whereas

Figure 4: Graphs showing the coordination of the articulatory gestures proposed for /s/ (top row), /n/ (middle row), and /l/ (bottom row) according their syllabic position: canonical coda on the left, derived onset in the middle, canonical onset on the right. Box sizes are not intended to iconically reflect acoustic duration. Solid lines represent in-phase coordination, dashed lines correspond to antiphase coordination. Abbreviations: crit. narr. (critical narrowing), TB (tongue-body), phar. approx. (pharyngeal approximation).



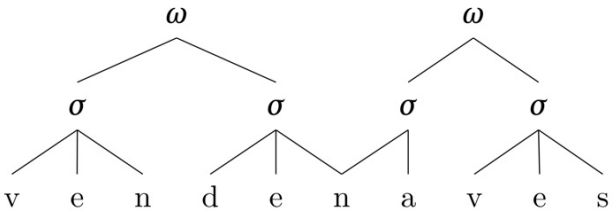
concatenated geminates correspond to two such units, albeit identical to each other. Such articulatory difference may account for other well-known phonetic and phonological differences between lexical and concatenated geminates.

A third piece of evidence in favor of the rearticulation of geminates is provided by Miller (1987) for Levantine Arabic, where spikes of energy corresponding to the subtle release bursts have been observed in the middle of geminate consonants on certain occasions. In line with Tilsen's view (2016), this is suggestive of the reselection of a previously executed motor plan, which results in a new constriction gesture to prolong the consonant. Following Tilsen's account, it is possible to interpret the appearance of such subtle bursts as arising from an inefficient internal feedback. Thus, the speaker must rely rather on the external feedback—i.e. the acoustic effect provided by the release—to detect when the gestural target has been reached prior to reselecting the motor commands that result in a geminate consonant.

Strycharczuk and Kohlberger (2016) discarded an ambisyllabic representation for derived onsets because they argued that such representation must be given to geminates. Our point is not to extend the data from the mentioned languages—Cypriot Greek or Levantine Arabic—to Spanish, but rather to show that ambisyllabicity is not a good analysis for geminates in a wide array of languages. Therefore, we argue that an ambisyllabic analysis remains available as a possible representation for derived onsets.

For all these reasons and as previously mentioned, there is sufficient evidence to interpret resyllabified consonants as onsets after the post-lexical reorganization of syllable structure occurring in resyllabification (see section 4.2). In addition to this, it is possible to consider that derived onsets still show coda properties (see sections 4.1 and 4.2) and have an intermediate status that points to an ambisyllabic representation (Figure 5).

Figure 5: *Venden aves* ('they sell birds'), ambisyllabic representation of derived onset /n/.



5. CONCLUSIONS

This study analyzes the acoustic duration of resyllabified consonants in Spanish as well as that of their flanking vowels. Derived onsets resulting from resyllabification present a shorter duration than their corresponding canonical onsets. This is interpreted as the consonant being lexically affiliated to the coda position, which is typically subject to weakening processes. Our results confirm this effect not only for /s/, as reported in the literature, but also for /n/ and /l/, which points to a shorter duration as the common cue to resyllabified consonants in Spanish.

Additionally, we argue that the durational differences observed for V1 and V2 between the derived and canonical conditions depend on the gestural configuration of the consonant. When comparing the possible interpretations accounting for such durational differences of the vowels, our results for V2 in the case of /l/ make it preferable to opt for an explanation entailing that the consonant also becomes the onset of the following syllable.

In summary, the acoustic duration of consonants and their flanking vowels in resyllabified contexts attest to the idea that those consonants simultaneously display properties typical both of codas and onsets, which is also supported by evidence previously reported in the literature. Consequently, we propose an ambisyllabic representation for derived onsets in Castilian Spanish.

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APPENDIX

Table A1: Details of participants.

Participant code	Gender	Age	Region of origin
AO	F	23	Extremadura
BS	F	21	Baleares
BT	F	22	Madrid
DM	M	49	Extremadura
ED	F	25	Madrid
EJ	F	24	Madrid
IB	F	20	Madrid
IM	F	21	La Mancha
JH	M	22	Madrid
LQ	M	21	Madrid
MA	F	21	Madrid
MD	F	22	Cataluña
MH	F	20	Madrid
MM	F	49	Madrid
NG	F	20	Madrid
PM	F	20	La Mancha
PP	M	21	Madrid
SB	F	22	Aragón
TH	F	19	Madrid

Table A2: Speech materials.

Paired sentences for /s/	
Cuando lanzas un dardo, evitas errar para no darle a nadie. (When you throw a dart, you avoid missing so as not to hit anyone.) *Ese pollo de corral necesitas hervirlo treinta minutos*. (That free-range chicken needs to be boiled for thirty minutes.) *Probablemente Marcos aluda a Paco para despistar*. (Marcos probably alludes to Paco in order to mislead the public.) *Te insultó diciendo que eras untuoso como el betún.* (S/He insulted you by saying that you were as greasy as bitumen.) *¿No buscabas ocio?* (Weren't you looking for entertainment?) *Con tanta mudanza, supongo que no querrás obras*. (With so much moving, I guess you don't want to do any construction work.) *Quizás urgían soluciones políticas*. (Perhaps political solutions were urgently needed.) *Juan supuso que eras ancho. Por eso te compró la talla más grande.* (Juan assumed you were wide-bodied.)	*Evita serrar cueste lo que cueste*. (Avoid sawing at all costs.) *Necesita servirlo a tiempo*. (S/He needs to serve it on time.) *Finalmente Marco saluda a Lorena desde el tren*. (Finally Marco greets Lorena from the train.) *Era suntuoso como el que más*. (It was as sumptuous as the best one.) *¿De verdad Bill Gates buscaba socio?* (Was Bill Gates really looking for an associate?) *Me imagino que no querrá sobras.* (I guess he doesn't want any leftovers.) *Dijo que quizá surgían ideas disparatadas*. (S/He said that crazy ideas might come up.) *Dijo que era Sancho*. (He said he was Sancho [a man's name].)
Paired sentences for /n/	
En el peor de los casos, ¿qué podrían hacer? (In the worst case, what could they do?) *Los consejeros delegados proponían hombres sabios para el comité.* (The CEOs proposed wise men for the committee.) *Veían algas en todas partes*. (S/He saw seaweed everywhere.) *Venden aves en el mercado regional de Toledo*. (They sell poultry in the regional market of Toledo.) *Tienen hormas nuevas*. (They have new shoe lasts.) *Preparan avíos para la campaña militar*. (They prepare travel gear for the trip.) *Veían arcos desde su ventana*. (They saw arches from their window.)	*Si el parto se complicara demasiado, ¿cómo podría nacer?* (If the delivery became too complicated, how could the baby be born?) *Proponía nombres nuevos cuando hacía falta*. (S/He proposed new names when needed.) *Veía nalgas a diario desde que trabajaba como enfermera*. (She saw buttocks every day since she worked as a nurse.) *Vende naves a buen precio*. (S/He sells ships at a good price.) *Tiene normas complicadas y sería bueno cambiarlas*. (It has complicated rules and it would be good to change them.) *Prepara navíos para el viaje*. (S/He prepares ships for the voyage.) *Veía narcos en el poblado gitano*. (S/He saw narcos in the gypsy settlement.)
Paired sentences for /l/	
Esa imagen del oro no se me borrará de la cabeza. (That image of the gold won't go out of my mind.) *He publicado la leyenda del ogro que me contaba siempre mi abuela*. (I have published the legend of the ogre that my grandmother would always tell me.) *Los caprichos del ego son incomprensibles*. (The whims of the ego are incomprehensible.) *Atraparon a la vil oca y la echaron a la cazuela*. (They caught the vile goose and threw it into the cooking pot.)	*Una jaula de loro es difícil de limpiar a conciencia*. (A parrot cage is difficult to clean thoroughly.) *Todavía no tenemos ningún indicio de logro que nos parezca convincente.* (We still don't have any convincing sign of success.) *Las ganancias de Lego se han multiplicado por tres este año*. (Lego's profits have increased threefold this year.) *Recuerdo que la vi loca y las gallinas salieron despavoridas*. (I remember that I saw her crazy and the hens ran away in panic.)