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Ambisyllabic characteristics of Spanish resyllabification: Beyond durational cues

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Abstract

In Spanish coda segments are resyllabified as the onset of a following onsetless syllable across a word boundary. Thus, *buscabas ocio* (‘you were looking for entertainment’) has been traditionally syllabified in the same way as *buscaba socio* (‘s/he was looking for an associate’), and both are considered homophones. In this study nineteen speakers were recorded producing sentences that included such two-word minimal pairs, making up a total of 1424 utterances. The acoustic analyses performed on both prosodic structures, i.e. /V#CV/ vs. /V#CV/, provide measures of amplitude, spectral characteristics, and coarticulation for /s/, /n/, and /l/, as well as for their flanking vowels. Our results show differences for each condition and suggest an ambisyllabic nature of resyllabified consonants, which is interpreted within the framework of Articulatory Phonology.

Keywords

Spanish; resyllabification; acoustic cues; articulatory gestures; ambisyllabicity

Característiques ambisil·làbiques de la resil·labificació en castellà: Més enllà de la durada

RESUM

En castellà, els segments de coda es resil·labifiquen a través d'un límit de paraula com a l'obertura d'una síl·laba següent quan aquesta no té obertura pròpia. Així, tradicionalment *buscabas ocio* ('buscaves oci') s'ha sil·labificat de la mateixa manera que *buscaba socio* ('buscava soci'), i totes dues sequències s'han considerat homòfones. En aquest estudi es van registrar dinou parlants produint frases que incloïen aquests parells mínims de dues paraules, per a un total de 1424 enunciats. Les anàlisis acústiques realitzades en ambdues estructures prosòdiques, és a dir, /V#CV/ vs. /V#CV/, proporcionen mesures d'amplitud, característiques espectrals i coarticulació per a /s/, /n/ i /l/, així com per a les vocals precedent i següent. Els nostres resultats mostren diferències per a cada condició i suggereixen una naturalesa ambisil·làbica de les consonants resil·labificades, que s'interpreta en el marc de la Fonologia Articulatòria.

MOTS CLAU

espanyol; resil·labificació; claus acústiques; gestos articulatoris; ambisil·labicitat

1. Introduction

Resyllabification is the post-lexical reorganization of syllable structure and is characterized by the realization of a word-final consonant as the onset of the following word (henceforth, derived onsets), so that an utterance such as *mis amigos* (‘my friends’) is syllabified as *mi.sa.mi.gos*. In the case of Castilian Spanish, resyllabification is considered to apply regardless of the identity of the consonant (Navarro Tomás, 1996 [1918], §§ 4, 154), although variation exists in other dialects of Spanish (e.g. Kaisse, 1999, for Argentinian Spanish; Robinson, 2012, for Ecuadorian Spanish; Trawick & Michnowicz, 2019, for Paraguayan Spanish).

Despite the fact that resyllabified sequences /VC#V/ were considered to be homophonous with their non-resyllabified counterparts /V#CV/ (Hualde, 2014 [2005], § 4.5.1), durational differences reported by several studies point to a distinction in the phonetic realization of target consonants, with derived onsets being consistently shorter than canonical onsets (Hualde & Prieto, 2014; Jiménez-Bravo & Lahoz-Bengoechea, 2023; Strycharczuk & Kohlberger, 2016). More precisely, Hualde and Prieto (2014) found shorter /s/ in Castilian Spanish and Catalan when realized as derived onsets /VC#V/ when compared to both canonical onsets /V#CV/ and word-medial onsets /V.CV/.

Such differences were confirmed by Strycharczuk and Kohlberger (2016), who analyzed the duration of Spanish derived onsets /s/ in several prosodic positions and showed durational differences along the following structures with word-internal codas displaying the shortest duration: Vs.C < Vs#C < Vs#V < V.sV < V#sV < Vs#sV. Strycharczuk and Kohlberger also reported that vowel segments preceding derived onsets and canonical onsets were longer than the vowels preceding codas — either word-final or word-medial codas —, although vowels preceding derived onsets did not present durational differences were compared to those vowels appearing before canonical onsets.

Similar results for differences in duration between both prosodic structures were also obtained for /s/ in Castilian Spanish by Jiménez-Bravo and Lahoz-Bengoechea (2023). That study analyzed sentences containing minimal pairs made up of two-word sequences, which only differed in the lexical affiliation not only of /s/ but also of other consonants undergoing resyllabification in Castilian Spanish, namely, /n/ and /l/. All three target consonants presented the same pattern of shorter derived onsets when compared to canonical onsets. In addition, this study also offered durational differences for the vowels surrounding the target consonants, and vowels preceding derived onsets /s/ — but not /n/ and /l/ — were shorter than those preceding their canonical onsets, while vowels following derived onsets /s/ and /n/ — but not /l/ — presented longer duration when compared to those vowels following canonical onsets. That paper interpreted such durational differences based on the articulatory gestures involved in the realization of each target consonant and discussed the possibility of considering derived onsets as ambisyllabic, given that derived onsets present both coda and onset properties.

In a follow-up study, it was analyzed whether, apart from duration, derived onsets /n/ differed from canonical onsets /n/ in their degree of nasal coarticulation with the previous vowel (Lahoz-Bengoechea & Jiménez-Bravo, submitted). That research applied the NAF method (Nasalization from Acoustic Features), developed by Carignan (2021), but failed to find differences in the degree of nasalization between both prosodic contexts.

Studies conducted for other languages not only support such durational differences in resyllabification contexts (e.g. for English: Lehiste, 1960; Smith & Hawkins, 2012; Tao et al., 2018; Turk & Shattuck-Hufnagel, 2000; for French enchaînement: Fougeron, 2007; Fougeron et al., 2003; Shoemaker, 2009; for Dutch: Quené, 1992; Shatzman & McQueen, 2006), but also point to a variety of other subphonemic differences between derived and canonical onsets (Boucher, 1988; Cutler & Carter, 1987; Lee et al., 2019; Lehiste, 1960; Modarresi et al., 2004; Quené, 1992). For example, in a lexical decision experiment conducted for English with minimal pairs (e.g. seem able vs. see Mable), Lehiste (1960) reported that derived onsets /m/ and /n/ showed a higher degree of laryngealization, with derived onsets /n/ also presenting lower F2 and a pattern of falling intensity. In the case of /l/, she reported differences in the formant structure of the consonant and different intensity patterns. Even if resyllabification in English could fail due to the occurrence of a glottal stop or an aspiration (e.g. Lee et al., 2019), resyllabified stops differ from their canonical onset counterparts in the relative duration of their closure relative to their entire duration (Boucher, 1988). Furthermore, the articulatory gestures involved in the realization of derived onsets have been observed to differ from those realized as canonical onsets (e.g. Modarresi et al., 2004).

Similar studies conducted for the phenomenon of French enchaînement[1] corroborated durational differences for an array of 4 target consonants in ambiguous two-word sequences such as *cale égale* ('equal wedge') and *cas légal* ('legal case'), with shorter duration for derived onsets (Fougeron et al., 2003; Fougeron, 2007; Shoemaker, 2009). According to Fougeron (2007), the duration of vowels preceding derived onsets was observed to be shorter only for certain target consonants, while vowels following derived onsets were longer than their counterparts following canonical onsets, yet again only for certain consonants. Such variety of results, which differ according to the identity of the consonant, was also found for other acoustic measures. For example, when the RMS amplitude was analyzed, lower values were observed for one out of 4 consonants as well as for vowels following derived onsets. As for the spectral moments, measured both for /s/ and /ʁ/, the center of gravity and the standard deviation of /ʁ/ presented significantly lower values for derived onsets, while skewness and kurtosis presented higher values, with no significant differences for /s/ in any of its spectral moments. Finally, differences were also found in F1, F2, and F3 for vowels both preceding and following derived onsets when compared to those surrounding canonical onsets, although such differences were reported according to vowel identity without presenting any consistent results.

As for Dutch, in a study into the perceptual differences of ambiguous word boundaries such as *diep in* ('deep in') or *die pin* ('that pin'), Quené (1992) similarly reported not only a shorter duration of derived onsets, but also a durational difference in their surrounding vowels. More precisely, vowels preceding derived onsets showed a shorter amplitude decay time — i.e. the duration from the maximal amplitude of the vowel to vowel offset —, which suggests a higher articulatory overlap of derived onsets with their preceding vowels in /VC#V/ sequences, and therefore a stronger coarticulation between them. In their turn, vowels following canonical onsets displayed a shorter amplitude rise time — i.e. the duration from vowel onset to its amplitude maximum —, also suggesting a stronger coarticulation between the target consonant and its following vowel in /V#CV/ sequences.

In the light of the results just described for both Spanish and other languages, the present study aims to extend the work presented in Jiménez-Bravo and Lahoz-Bengoechea (2023) on the durational cues of resyllabification, and that described in Lahoz-Bengoechea and Jiménez-Bravo (submitted) on nasal coarticulation, by assessing other possible acoustic cues to resyllabification in Castilian Spanish.

2. Methods

This study is an extension of a previous study (Jiménez-Bravo & Lahoz-Bengoechea, 2023). Methodological aspects regarding the participants and procedures are similar to that paper and are therefore presented here only in a summarized fashion.

[1] Enchaînement (and not liaison) is the most similar phenomenon to Spanish resyllabification. Liaison involves the emergence of an underlying consonant that is not pronounced in contexts in which the linking between words does not take place (i.e. when there is no vowel-initial word). On the contrary, words subject to enchaînement do present an overt final consonant whether or not they are linked to the following word (Spinelli et al., 2002).

2.1. Participants

Nineteen native speakers of Castilian Spanish took part in this study. All of them were university students aged 18–26, and the sample consisted of 15 women and 4 men (we did not attach any importance to the lack of balance in terms of gender since we did not hypotesize this variable to play any relevant role in the production of resyllabified consonants). Two of the subjects were bilingual speakers of Catalan, although their pronunciation was not different from that of the monolingual speakers of Spanish, as assessed more in detail in section 2.4. Therefore they were retained in the analysis together with monolingual participants and bilingualism was not considered a variable in this study.

2.2. Materials and procedure

Participants were recorded producing sentences with two experimental conditions: target consonants — either /s/, /n/, or /l/ — could appear as canonical (V#CV) or as derived onsets (VC#V). Each sentence was paired with another, such that the VCV sequence was embedded in a two-word minimal pair (e.g. *buscaba socio* vs. *buscabas ocio*); see Table i in the Appendix.

The strength of the prosodic boundary between the two words was the same for each member of a given pair of sentences. In order to prevent participants from becoming aware of this relationship, each sentence of a pair was recorded in a different session. The analysis was conducted on a total of 1424 uttered sentences, namely 8 pairs of sentences with /s/, 7 with /n/, and 4 with /l/, with 2 repetitions of each sentence per subject. Not all consonants lend themselves equally well to building meaningful paired sentences, hence the difference in quantity with one consonant or another. The design would total 1444 samples (19 subjects × [8+7+4] pairs × 2 sentences in each pair × 2 repetitions), although some repetitions of certain subjects were discarded due to the presence of an artificial pause in the middle of the sentence, thus yielding a final count of 1424 analyzable tokens.

For more details about the experimental procedure, such as the recording equipment and the segmentation criteria, see Jiménez-Bravo and Lahoz-Bengoechea (2023).

2.3. Acoustic measures

By means of a *Praat* script the following measures were calculated:

a) Root-mean-square amplitude of the three target consonants and their preceding (V1) and following (V2) vowels.
b) Spectral characteristics of /s/. The first four spectral moments were measured: centre of gravity, standard deviation, skewness, and kurtosis.
c) Spectral characteristics of /n/, /l/, V1 and V2. The first three formants were measured using the Burg algorithm at 5 different points: 0%, 25%, 50%, 75%, and 100% of the duration of the segment.
d) Bandwidth of the first three formants.
e) ADT and ART. Following Quené (1992), the degree of coarticulation was measured as the amplitude decay time (ADT) of V1, i.e. the duration elapsed between the maximal amplitude of the vowel and its offset. Similarly, the amplitude rise time (ART) was also measured, i.e. the duration elapsed between the onset of V2 and its maximal amplitude.

2.4. Statistical analyses

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. The several acoustic measures extracted from 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. 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 within speaker.

Despite having a similar pronunciation to monolingual speakers, the two bilingual participants were analyzed for those acoustic characteristics that might be expected to differ according to their linguistic background. In order to do so, Bilingual was added as a fixed predictor, together with its interaction with Condition, as in Strycharczuk and Kohlberger (2016). The absence of significance justified the decision to keep these participants in our analyses. Therefore Bilingual was not included in the models reported in the Results section.

For more detail and to abide by standards of reproducible research, all analysis scripts and data are permanently made public under this link: https://osf.io/nw648/?view_only=f04499e880bb4c75a7336121bffbbbaf

3. Results

3.1. RMS amplitude

As for the RMS amplitude, all three target consonants showed lower values when in derived onset position: 2.0 mPa lower for /s/ ($SE = 0.6$, $t = -3.29$, $p = .001$), 6.4 mPa for /n/ (SE = 1.8, $t = -3.51$, $p = .002$) and 4.4 mPa for /l/ ($SE = 1.6$, $t = -2.69$, $p = .009$). A similar decrease in the RMS of both contextual vowels was observed, and in the case of derived onsets /s/, values were 5.3 mPa lower for V1 ($SE = 1.8$, $t = -2.95$, $p = .005$) and 3.6 mPa lower for V2 ($SE = 1.7$, $t = -2.15$, $p = .044$). The RMS amplitude of vowels surrounding /n/ was 7.4 mPa lower for V1 ($SE = 2.0$, $t = -3.70$, $p < .001$) and 7.8 mPa lower for V2 ($SE = 2.0$, $t = -3.96$, $p < .001$). As for derived onsets /l/, the RMS value was 6.3 mPa lower for V1 ($SE = 2.1$, $t = -3.0$, $p = .006$) and 4.5 mPa lower for V2 ($SE = 1.9$, $t = -2.41$, $p = .020$) (Figure 1, see Table 1 for descriptive values).

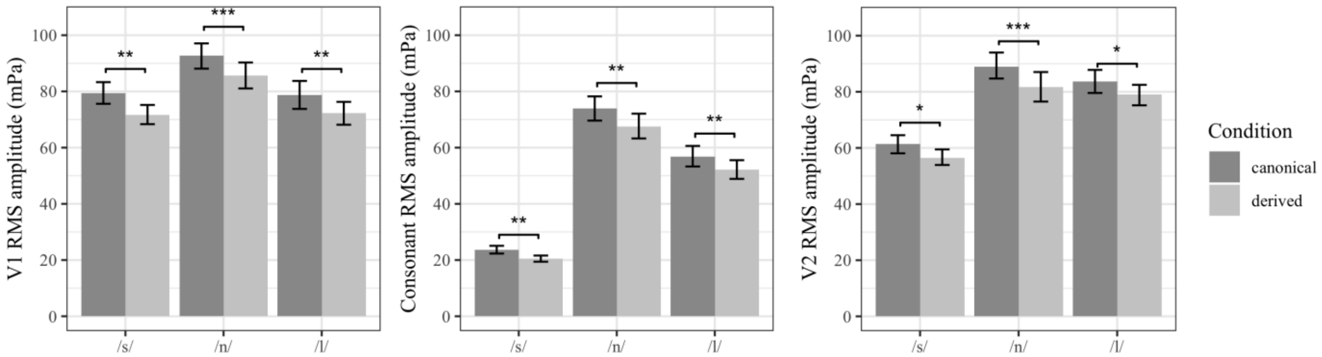

Figure 1. Differences for RMS amplitude for all three target consonants and their surrounding vowels. CIs at 95%.

	/s/		/n/		/l/	
	Canonical	**Derived**	**Canonical**	**Derived**	**Canonical**	**Derived**
V1	79 (34)	72 (29)	93 (37)	86 (38)	79 (31)	72 (25)
C	24 (12)	20 (10)	74 (36)	68 (37)	57 (23)	52 (21)
V2	61 (29)	57 (24)	89 (39)	82 (39)	84 (26)	79 (23)

Table 1. Values for RMS amplitude in mPa: M (SD).

3.2. Spectral characteristics

In the case of /s/, the spectral analysis is based on the first four spectral moments, as is usually done in the literature. The centre of gravity proved significant, and derived onset /s/ showed 423 Hz lower than canonical onset /s/ (*SE* = 93, *t* = −4.55, *p* < .001). Furthermore, the distribution of frequencies showed a stronger representation of the lower frequencies, as shown by the positive skewness (0.21) of derived onsets respect to canonical onsets (*SE* = 0.06, *t* = 3.43, *p* < .001) (Figure 2). The remaining two spectral moments were not significant (standard deviation: *β* = −5, *SE* = 47, *t* = −0.10, *p* = .920; kurtosis: *β* = 0.10, *SE* = 0.24, *t* = 0.41, *p* = .685) (see Table 2 for descriptive values).

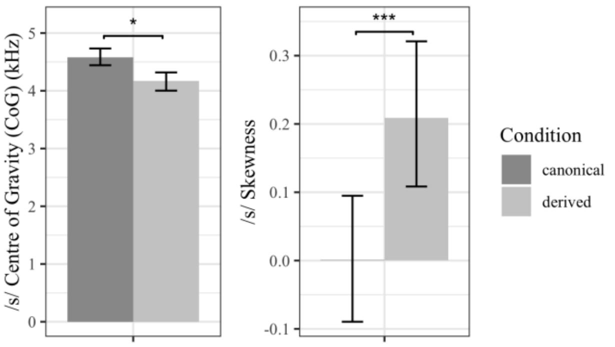

Figure 2. Significant spectral moments of /s/: Centre of Gravity (CoG) and skewness. CIs at 95%.

	Canonical	Derived
CoG (Hz)	4583 (1299)	4170 (1345)
St. Dev. (Hz)	2670 (624)	2662 (603)
Skewness	0.00 (0.80)	0.21 (0.91)
Kurtosis	0.72 (2.68)	0.82 (3.50)

Table 2. Values for /s/ spectral moments: M (SD).

Formant values for the vowels surrounding /s/ are given in Table 3. For V1, we observed a lower F1 at the following timepoints: 25% (*β = −18, SE* = 7, *t* = −2.63, *p* = .016), 50% (*β* = −26, *SE* = 7, *t* = −3.58, *p* = .002), 75% (*β* = −17, *SE* = 8, *t* = −2.11, *p* = .048), and 100% (*β* = −29, *SE* = 13, *t* = −2.28, *p* = .034). None of the measures taken for the other formants differed significantly between the canonical and the derived condition in any timepoint of V1.

For V2, only F2 consistently differed between conditions, with lower values for vowels following derived onsets /s/ at the 25% (*β* = −39, *SE* = 17, *t* = −2.23, *p* = .039) and at the 75% (*β* = −35, *SE* = 16, *t* = −2.24, *p* = .033), with the timepoint at 50% possibly being an accidental gap, which is in any case close to significance (*β* = −24, *SE* = 14,

		0%		25%		50%		75%		100%	
		Can.	**Der.**	**Can.**	**Der.**	**Can.**	**Der.**	**Can.**	**Der.**	**Can.**	**Der.**
F1	**V1**	552 (109)	545 (110)	651 (103)	634 (96)	696 (107)	670 (103)	663 (118)	646 (113)	604 (148)	575 (141)
	V2	489 (144)	497 (163)	564 (147)	558 (156)	570 (144)	567 (152)	545 (144)	543 (143)	481 (128)	486 (129)
F2	**V1**	1642 (325)	1630 (286)	1589 (296)	1593 (248)	1614 (236)	1600 (213)	1643 (221)	1633 (198)	1763 (180)	1727 (161)
	V2	1663 (256)	1647 (239)	1565 (278)	1529 (273)	1522 (282)	1501 (273)	1514 (285)	1482 (268)	1528 (270)	1522 (268)
F3	**V1**	2628 (298)	2584 (291)	2472 (336)	2444 (328)	2534 (331)	2496 (319)	2661 (315)	2606 (299)	2835 (258)	2848 (255)
	V2	2827 (284)	2821 (293)	2721 (282)	2655 (283)	2654 (286)	2616 (295)	2609 (295)	2599 (294)	2655 (272)	2622 (285)

Table 3. Formant values in Hz for vowels surrounding target consonant /s/: M (SD). (Can. = canonical onset, Der. = derived onset).

$t = -1.78$, $p = .092$). For V2, there were no consistent differences in any other formant.

Given that F2 significantly varies according to vowel timbre, the result was further analyzed separately for each V2 identity (Figure 3). A Tukey post-hoc comparison between conditions for each vowel revealed a consistent difference in F2 values for /e/ at the 0% ($\beta = -107$, $SE = 28$, $t = -3.85$, $p = .004$), 25% ($\beta = -97$, $SE = 28$, $t = -3.44$, $p = .017$), 50% ($\beta = -81$, $SE = 26$, $t = -3.08$, $p = .046$), and 75% ($\beta = -98$, $SE = 26$, $t = -3.73$, $p = .006$) timepoints. No difference was found between conditions for any of the other vowels.

Turning to consonant /n/, formant values (F1-F3) of V1 were not significantly affected by the derived onset condition. The formant values of both the consonant and V2 were not consistently affected by the effect of the condition either (see descriptive values in Table 4). In the case of /l/, the effect of condition was non-significant for any of the first three formants in the target consonant and its flanking vowels (see Table 5).

As for the bandwidth, none of the measures was significantly different as a result of the lexical affiliation of the target consonant.

3.3. Coarticulation

Finally, in order to complement the spectral measures reported thus far for the consonants and their contextual vowels, the Amplitude Decay Time (ADT) and the Amplitude Rise Time (ART) were calculated — as proposed by Quené (1992) — and used as measures of the coarticulation with V1 and V2, respectively (Table 6). In the case of /s/, V1 was more coarticulated when it was unstressed, or in other words, ADT was 8.5 ms longer in stressed syllables, almost reaching significance ($SE = 3.8$, $t = 2.22$, $p = .051$). When considering only unstressed instances of V1, derived onsets /s/ barely differed in ADT with respect to their canonical onset counterparts. However, the derived onset condition did present a significantly increased degree of VC coarticulation (ADT was 6.8 ms shorter) with respect to the canonical onset when this condition interacted with the stressed nature of V1 ($SE = 2.4$, $t = -2.77$, $p = .006$).

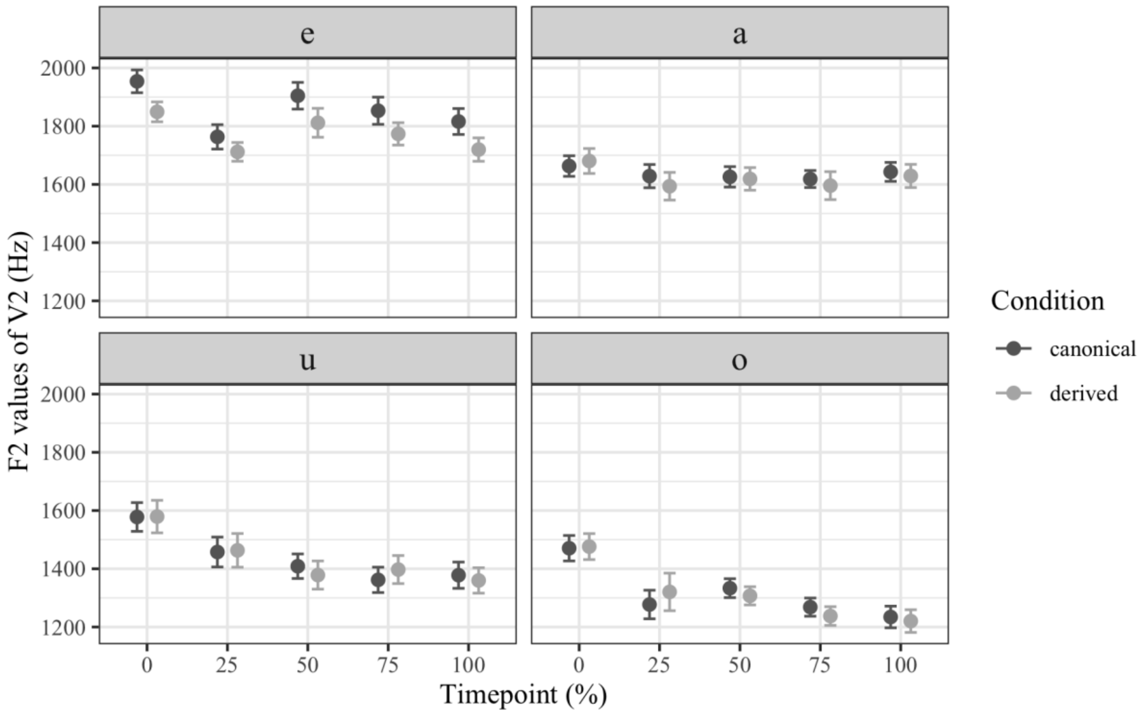

Figure 3. Time progression over the vowel following /s/ of mean F2 values for the different vowel identities. CIs at 95%.

		0%		25%		50%		75%		100%	
		Can.	**Der.**	**Can.**	**Der.**	**Can.**	**Der.**	**Can.**	**Der.**	**Can.**	**Der.**
F1	**V1**	562 (134)	557 (131)	660 (137)	657 (135)	700 (146)	701 (150)	705 (146)	702 (150)	598 (143)	582 (146)
	C	598 (143)	582 (146)	447 (150)	435 (138)	438 (156)	418 (139)	423 (138)	422 (147)	555 (162)	553 (165)
	V2	555 (162)	553 (165)	743 (142)	745 (150)	773 (138)	764 (155)	749 (135)	742 (141)	638 (147)	620 (157)
F2	**V1**	1916 (356)	1934 (375)	1929 (318)	1913 (336)	1840 (304)	1841 (329)	1779 (295)	1793 (283)	1722 (252)	1724 (258)
	C	1722 (252)	1724 (258)	1714 (263)	1686 (271)	1659 (267)	1669 (257)	1633 (231)	1625 (210)	1603 (193)	1592 (184)
	V2	1603 (193)	1592 (184)	1586 (197)	1582 (206)	1539 (212)	1545 (220)	1536 (221)	1531 (233)	1509 (200)	1521 (217)
F3	**V1**	2665 (301)	2645 (324)	2635 (339)	2591 (383)	2602 (351)	2544 (401)	2538 (384)	2498 (384)	2527 (384)	2537 (372)
	C	2527 (384)	2537 (372)	2543 (344)	2515 (324)	2510 (329)	2517 (312)	2509 (299)	2501 (271)	2452 (372)	2445 (335)
	V2	2452 (372)	2445 (335)	2368 (394)	2371 (357)	2367 (368)	2425 (352)	2407 (363)	2495 (332)	2489 (314)	2526 (336)

Table 4. Formant values in Hz for target consonant /n/ and its surrounding vowels: M (SD).
(Can. = canonical onset, Der. = derived onset).

		0%		25%		50%		75%		100%	
		Can.	**Der.**	**Can.**	**Der.**	**Can.**	**Der.**	**Can.**	**Der.**	**Can.**	**Der.**
F1	**V1**	463 (90)	455 (93)	483 (79)	490 (90)	496 (97)	505 (98)	488 (90)	499 (90)	431 (68)	437 (66)
	C	431 (68)	437 (66)	377 (57)	390 (60)	374 (54)	378 (47)	370 (45)	376 (44)	447 (61)	446 (59)
	V2	447 (61)	446 (59)	545 (65)	543 (69)	559 (77)	558 (72)	536 (75)	542 (75)	494 (96)	498 (77)
F2	**V1**	1743 (236)	1769 (211)	1860 (297)	1907 (286)	1941 (323)	1955 (284)	1980 (309)	1996 (276)	1934 (238)	1924 (211)
	C	1934 (238)	1924 (211)	1840 (224)	1855 (208)	1819 (197)	1805 (191)	1758 (203)	1796 (181)	1769 (195)	1764 (192)
	V2	1789 (195)	1764 (192)	1661 (265)	1637 (286)	1479 (293)	1496 (319)	1365 (256)	1359 (269)	1336 (249)	1322 (242)
F3	**V1**	2653 (266)	2660 (286)	2628 (303)	2649 (282)	2677 (288)	2695 (270)	2706 (270)	2697 (297)	2749 (268)	2758 (232)
	C	2749 (268)	2758 (232)	2794 (200)	2799 (204)	2781 (220)	2775 (201)	2775 (210)	2755 (213)	2622 (234)	2603 (238)
	V2	2622 (234)	2603 (238)	2597 (239)	2588 (273)	2582 (224)	2574 (266)	2568 (280)	2583 (259)	2578 (331)	2572 (317)

Table 5. Formant values in Hz for target consonant /l/ and its surrounding vowels: M (SD).
(Can. = canonical onset, Der. = derived onset).

	/s/		/n/		/l/	
	Canonical	**Derived**	**Canonical**	**Derived**	**Canonical**	**Derived**
ADT (unstressed)	46.9 (14.9)	46.7 (14.2)	37.5 (16.3)	39.2 (17.5)	31.5 (16.3)	30.5 (16.0)
ADT (stressed)	55.4 (17.4)	48.4 (14.1)	—	—	47.6 (25.3)	46.3 (22.2)
ART (unstressed)	30.4 (15.1)	29.6 (15.1)	30.7 (18.1)	32.2 (19.6)	—	—
ART (stressed)	27.9 (13.5)	32.0 (17.1)	40.8 (18.5)	41.8 (21.5)	36.1 (22.4)	34.8 (24.3)

Table 6. Coarticulation values expressed as amplitude decay time (ADT) and amplitude rise time (ART) for unstressed and stressed vowels: M (SD).

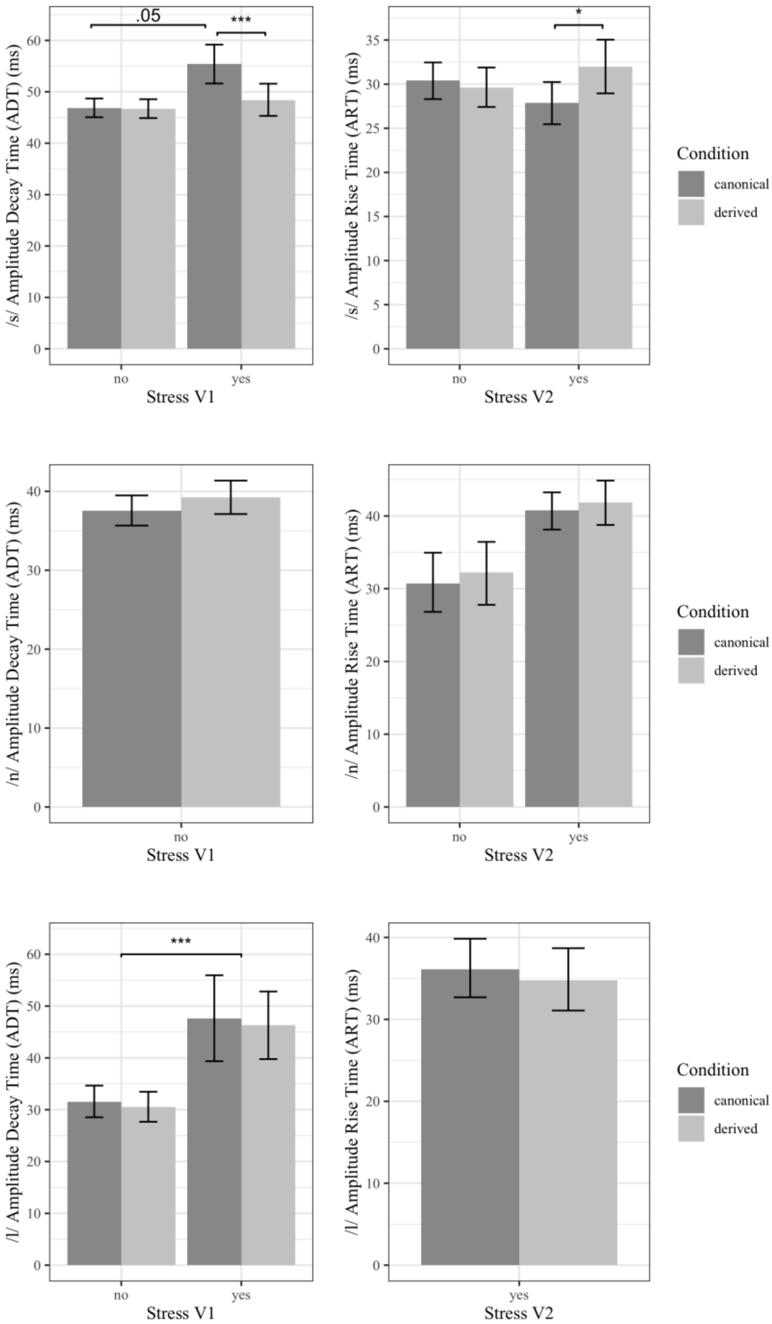

Figure 4. VC coarticulation as ADT (amplitude decay time) and CV coarticulation as ART (amplitude rise time) for all three target consonants /s/ (top panel), /n/ (middle panel), and /l/ (bottom panel). CIs at 95%.

In the case of ART, the stress of V2 did not significantly influence the degree of coarticulation of /s/; however, as observed in ADT, the interaction between condition and stress also proved significant. In this case, there was less CV coarticulation as a result of the derived condition in stressed syllables, with an increase of 4.9 ms in ART ($SE = 2.4$, $t = 2.05$, $p = .041$) (Figure 4). No significant differences were observed in the case of /n/ and /l/ for either ADT or ART.

4. Discussion and conclusions

Nineteen speakers of Castilian Spanish were recorded producing sentences with two experimental conditions: target consonants — either /s/, /n/, or /l/ — could appear as canonical (V#CV) or as derived onsets (VC#V). Each sentence was paired with another, such that the VCV sequence was embedded in a two-word minimal pair (e.g. *buscaba socio* vs. *buscabas ocio*).

4.1. RMS amplitude

Our results showed that the RMS amplitude behaved similarly for all three target consonants and was consistently lower for the whole VCV sequence in the derived-onset condition. These results are in line with the observations made by Lehiste (1960), who reported that derived onsets were produced with less intensity.

The lower value of the RMS amplitude of derived onsets is compatible with the idea that these consonants retain the weak character of codas as would be expected from their lexical affiliation. In the framework of Articulatory Phonology, this weakness has been explained by the anti-phase coordination that codas have with respect to their nuclear vowel, since such coordination mode is more unstable (Browman & Goldstein, 1992, 1995; Goldstein et al., 2006, p. 229).

The reduced amplitude also observed for both flanking vowels cannot be possibly attributed to anything but the different lexical affiliation of the consonant. Additionally, since this affects both vowels similarly, the explanation should be related to a common trait in their respective relationship to the consonant. Our proposal is that both vowels belong to the same syllable as the consonant or, in other words, that the consonant becomes ambisyllabic after the post-lexical reorganization.

This interpretation supports the idea put forward in a previous study based on durational data (Jiménez-Bravo & Lahoz-Bengoechea, 2023). The results of that study showed that derived onset /s/, /n/, and /l/ are shorter than their canonical-onset counterparts, in line with the weak character of their original coda position. On the other hand, the durational behavior of flanking vowels allowed to identify also onset properties in the resyllabified consonants. Specifically, the vowel following derived onset /l/ was similar in duration to the one following a canonical onset. The behavior of /l/, different from /s/ and /n/, is accounted for by its constituency in terms of articulatory gestures as explained in that paper (Jiménez-Bravo & Lahoz-Bengoechea, 2023). As can be seen in Figure 5, the

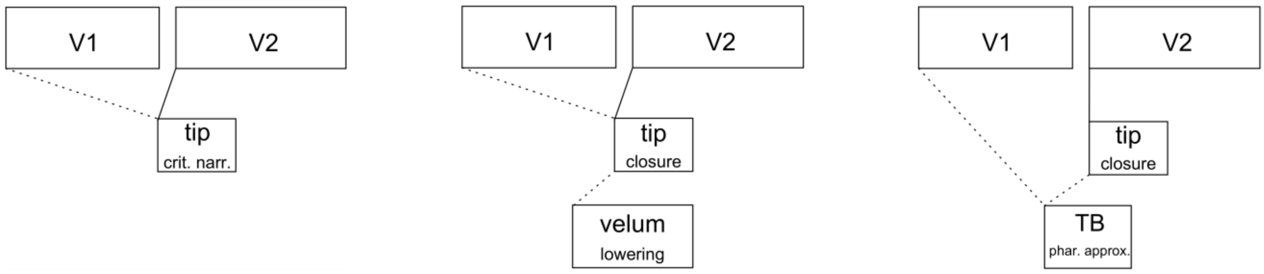

Figure 5. Graphs showing the coordination of the articulatory gestures proposed for the derived onsets analyzed in this study (/s/ on the left, /n/ in the middle, /l/ on the right). Solid lines represent in-phase coordination and dashed lines correspond to antiphase coordination. Abbreviations: crit. narr. (critical narrowing), TB (tongue-body), phar. approx. (pharyngeal approximation). Taken from Jiménez-Bravo and Lahoz-Bengoechea (2023, Figure 3).

degree of overlap between the consonants and their flanking vowels depends on the compromise attained between the articulatory gestures linked in phase (onset) and anti phase (coda). The ambisyllabic configuration of derived onsets leads to an anticipation of the beginning of the consonantal gesture, which therefore overlaps more with V1 and less with V2 (in comparison with canonical onsets), with the exception of /l/ motivated by its having two lingual gestures.

An anonymous reviewer suggested that, since our corpus does not include canonical codas as a control group, it cannot be ruled out that the consonants studied have not undergone resyllabification at all. However, the option that these segments still belong only to the coda can be discarded based on our data. As just mentioned, in our previous study the duration of the vowel following /l/ was similar to that of canonical onsets. On the other hand, a hypothetical canonical coda status of the consonant would not explain why V2, despite belonging to another syllable and another word, sees its RMS amplitude decreased as shown in the results of the present paper.

An alternative account might be that the consonants studied could have undergone full resyllabification and belong only to the onset, but differ from canonical onsets as a means of marking word boundaries. However, in that case, what would remain unexplained would be the decrease in RMS amplitude of V1. Furthermore, if resyllabification were complete, π-gestures should not affect those consonants differently from canonical onsets (bear in mind that π-gestures take prosodic structure into consideration and affect duration and magnitude in the development of constriction gestures, see Byrd & Saltzman, 2003). A fully word-initial gesture would undergo strengthening, not weakening phenomena as found in our data.

In short, as explained above, the similar behavior of the RMS amplitude of V1, the consonant, and V2, points to all three sharing some structural characteristic, and that must be that they belong to the same syllable.

Of all the acoustic measures included in the previous and the present study, both the shorter temporal realization and the lower RMS amplitude of derived onsets are the only aspects common to all three studied consonants. Other than that, segment-specific cues were also observed here. In this sense, such differences might be due to the specific articulatory gestures involved in their production, as will be next discussed.

4.2. Spectral characteristics

For the spectral moments of derived onset /s/, a positive skewness was found, which is in turn related to the lower centre of gravity also observed. A likely interpretation is that derived onset /s/ is hypoarticulated due to its being associated to a coda position, which is actually consistent with its shorter duration and lower amplitude. In this sense, the resulting narrowing of the fricative is expected to be of a lesser degree, and this might explain the overall lowering of the frequencies generated by the sibilance.

The lower value of F1 during V1 could be accounted for by the relative anticipation of the tongue-tip gesture, namely, of the constriction in the frontal half of the vocal tract (Stevens, 1998).

That anticipation of the consonantal gesture may also explain the relatively lower F2 value displayed during V2 in the derived condition. This might be due to the reduced coarticulation between this vowel and /s/, whereas in the canonical condition the consonant might on the contrary attract that vowel formant to higher frequencies. In fact, Figure 3 shows that those V2 timepoints closer to /s/ actually display a higher value of F2, thus supporting the interpretation that the lesser the coarticulation, the lower the F2.

This coarticulatory effect is more evident in the case of frontal vowel /e/, which may be due to its F2 range being closer to the attracting pole of /s/. This may likely be the reason why it is /e/ that shows the largest F2 difference between the derived onset and the canonical onset conditions.

As for /n/ and /l/, instead of spectral moments, formant values were measured, and none of them showed any significant effect of condition for any of the two consonants or for their flanking vowels.

4.3. Coarticulation

As a complement to the spectral measures, coarticulation was also assessed by means of two parameters — Amplitude Decay Time (ADT) and Amplitude Rise Time (ART) —, as proposed by Quené (1992). The choice of these measures provides a way to compare among the three target consonants despite their inherent acoustic particularities. According to Quené, these measures account for the VC and the CV coarticulation, respectively. To the best of our knowledge, these measures have not been used by any other authors for the same purpose, nor has any paper proved their validity as measures of coarticulation. However, both Quené's and our own data are compatible with a coarticulatory interpretation.

In our results, no significant variation of ADT was found as a main effect for any of the three consonants. Nonetheless, /s/ did show an interaction between condition and stress. When V1 was stressed, the derived onset configuration was associated to a decrease in ADT, corresponding to a greater degree of VC coarticulation. This is in agreement with the shorter V1 duration found for derived onset /s/ (Jiménez-Bravo & Lahoz-Bengoechea, 2023). A similar effect could be expected for unstressed V1. However, ADT was considerably low — namely there was a fair amount of VC coarticulation —, but there was no distinction between the canonical and the derived conditions.

Likewise, an interaction between condition and stress was also observed for /s/ in the analysis of Amplitude Rise Time. When V2 was stressed, there was a longer ART in the derived onset, which might be interpreted as a reduction of the CV coarticulation. This is consistent with the longer V2 duration found in this case, as previously reported (Jiménez-Bravo & Lahoz-Bengoechea, 2023). In the case of unstressed V2, no differences were observed between the canonical and the derived conditions.

In the case of derived onset /n/, no significant effect was found for any of the coarticulatory measures (ADT or ART). This is in line with the similar degree of nasal coarticulation in VN observed for both conditions in Lahoz-Bengoechea and Jiménez-Bravo (submitted), a study applying the NAF method (Nasalization from Acoustic Features) proposed by Carignan (2021). Solé (1992, 1995) interprets this lack of difference in the degree of coarticulation as Spanish nasalization being a purely phonetic process that operates locally around the consonant boundary. This is independent of the phonological structure in which it appears, namely whether or not the articulatory gestures of the consonant are coordinated with the previous vowel.

As for /l/, neither ADT nor ART showed any significant effects when comparing derived to canonical onsets. The lack of differences in ADT may be due to the fact that the tongue-body gesture of /l/, despite overlapping with V1, is vocalic in nature (Proctor, 2009). One possible interpretation is that the ADT measure might not be sensitive enough to that kind of coarticulation between vocalic gestures. Another one is that there might be a lesser degree of coarticulation when both segments involve the same organ (Recasens, 1999).

4.4. Conclusions

Several acoustic characteristics were analyzed in Spanish two-word minimal pairs inserted in sentences. These pairs reflect what has traditionally been dubbed resyllabification, which is described as the realization as onset of a coda consonant before a following vowel across a word boundary. For example, /V#CV/ as in *buscaba socio* ('s/he was looking for an associate') forms a minimal pair with /VC#V/ as in *buscabas ocio* ('you were looking for entertainment'), and both have been commonly considered to be homophonous after resyllabification of the latter as *bus.ca.ba.so.cio*.

Nevertheless, this paper contributes further acoustic differences beyond the durational cues previously reported in the literature, thus reinforcing the alternative view that resyllabification actually does not give rise to homophonous pairs. Of all the measures taken into account in this study, a difference between /V#CV/ (canonical onset condition) and /VC#V/ (derived onset condition) was observed for the RMS amplitude, some spectral characteristics, and coarticulation measures such as amplitude decay time (ADT) and amplitude rise time (ART).

These acoustic cues, being of a varied nature, offer converging evidence that is here accounted for in terms of the temporal coordination of articulatory gestures. We suggest that resyllabified consonants do not only acquire onset properties but also retain those of their original coda position, therefore being ambisyllabic.

In order to corroborate the validity of this analysis, it would be desirable to study the behavior of derived onsets from the articulatory point of view, perhaps with some imaging technique such as UTI. Additionally, it should be investigated to what extent listeners are able to perceptually exploit at least some of these acoustic cues to disambiguate the lexical affiliation of the consonant.

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Declaration of conflict of interest

The authors declare they have no potential conflict of interest with this publication.

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Appendix

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

Table i. Speech materials.