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Acquisition of codas in Spanish as a first language:

The role of accuracy, markedness, and frequency

Abstract

Studies on the acquisition of Spanish as a first language do not agree on the patterns and factors relevant for coda development. In order to shed light on the questions involved, a longitudinal study of coda development in Northern European Spanish was carried out to explore the relationship between accuracy, markedness, and frequency. 8517 intended codas produced by two children from 1;7 to 2;7 years old were analyzed. The main contribution of this study comes from the analysis of substitutions. The children produced more codas and more accurate codas in stressed syllables, particularly in word final position before the age of 2, but after 2 years old their coda production was target-like in stressed medial position. They substituted phones in unstressed and in word final position. It is argued that the most salient and frequent characteristics of Spanish syllables structure enhance coda development in the early years. Only after the establishment of the syllable structure do children focus on segmental quality, which results in target-like acquisition of Spanish codas following markedness predictions. Substitution patterns are independent of syllable structure: sonorant codas are substituted with a sonorant, and obstruents with an obstruent regardless of stress and position.

Keywords

Codas, Spanish, first language, prosodic development, frequency, markedness, accuracy

Introduction

Studies on language development that focus on the acquisition of prosodic patterns tend to explore word shape, stress and syllable structure, e.g., consonant cluster reductions, coda deletion, and consonant/glide epenthesis (Rose & Inkelas, 2011). Coda development emerges as an interesting area of research given that syllables with codas are phonologically more complex than syllables that lack them, and, furthermore, that codas are phonotactically restricted in many languages and are universally weaker than onsets (Clements, 1990; Blevins, 1995; Zec, 1995). This status of codas cross-linguistically predicts that their acquisition poses challenges for children. However, there is still much to be learned about the prosodic organization of children's utterances, and the paucity of prosodic development studies is especially notorious in Spanish (Lleó, 2012). The purpose of this study is to further advance our understanding of the development of codas in Spanish and broaden the field of prosodic acquisition in this language.

Coda development across languages

Standard models of prosodic development posit that across languages children expand their syllable structure to allow for (i.e. license) syllable codas, while also allowing for different types of phones within this position (Fikkert, 1994; Freitas, 1997). CV (i.e. Consonant Vowel) is the unmarked universal syllable structure, and the first to be acquired. CVC, syllable with a coda, appears in a second stage of syllable development (Fikkert, 1994; Stemberger, 1996; Levelt et al., 2000; Yuen et al., 2015). Codas can appear earlier in languages where they are prosodically licensed, i.e. where codas play a role in the syllabic weight statement like in English, but not in Spanish (Miles et al., 2016).[1] For instance, Spanish [pa.ˈɾa.ɣwas] *paraguas* (‘umbrella’) is produced as [pa.ˈwa] at 1;9, as [ba.ˈba.bwa] at 1;11, and only, when fricatives codas can be produced, as [pa.ˈða.ɣwas] at 2;3.[2]

Previous studies of coda development have paid attention to different factors: the position of the syllable within the word (i.e. whether the coda appears in word-medial or word-final position), stress (i.e. whether the coda appears in a stressed or an unstressed syllable), the type of coda segment, and the frequency of codas in the target language.[3]

Regarding word position, final codas (CV.CVC) have been found to be acquired earlier than medial ones (CVC.CV) in Dutch (Fikkert, 1994), French (Rose, 2000), English

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1 The majority of authors consider that Spanish is not sensitive to syllabic weight.
[2] All the examples in the paper belong to the corpus of the present research.
[3] Several studies analyse morphological codas, i.e. suffixes, as another factor of prosodic development. In the current research morphology is set aside for future analyses.

(Kirk & Demuth, 2006), and Catalan (Prieto, 2006; Borràs-Comes & Prieto, 2013). Nevertheless, in Spanish there is no consensus: some authors report that Spanish-speaking children prefer final codas (Oropeza Escobar, 2001), others that they prefer medial codas (Lleó, 2003), and other authors do not find any differences by position (Nuñez-Cedeño, 2007). Rose (2003) establishes that if codas are place-specified in Spanish, final codas will be acquired earlier than medial codas; however, if Spanish children are sensitive to the distributional patterns of Spanish codas, medial and final codas will be acquired during similar stages.

As for stress, authors argue that codas are acquired in stressed syllables before unstressed syllables, for instance, in English (Zamuner & Gerken, 1998; Kirk & Demuth, 2006), Spanish (Lleó, 2003; Saceda Ulloa, 2005) European Portuguese (Freitas et al., 2001), Japanese (Ota, 1999), and Catalan (Prieto & Bosch-Baliarda, 2006; Borràs-Comes & Prieto, 2013).

In terms of segment type, data from English, Spanish and Catalan (Oropeza Escobar, 2001; Lleó et al., 2003; Morales-Front, 2006; Borràs-Comes & Prieto, 2013) suggest that children first fill the coda position with a glide ([w, j]). In Spanish, previous studies agree that nasals are the first coda consonants to be acquired and rhotics the last (Goldstein & Cintrón, 2001; Núñez-Cedeño, 2007; Fernández López, 2009). However, there is disagreement as to the acquisition order of other types of consonants, with some authors claiming that laterals and fricatives are acquired at roughly the same time after nasals (Macken, 1978), and others arguing that fricatives are acquired before laterals (Carreira, 1991).

Phonological markedness seems to account for coda development, since the first segments to be acquired are sonorants, which occupy the highest position in the sonority hierarchy (Clements, 1990), and this makes them less marked as coda elements. For instance, in Spanish, sonorants are the first codas to be acquired (Núñez-Cedeño, 2007; Lleó, 2012.) However, obstruent codas are acquired before sonorant codas in Dutch (Fikkert, 1994; Levelt et al., 2000), English (Kehoe & Stoel-Gammon, 2001), Portuguese and French (Goad, 1998; Freitas et al., 2001; Almeida, 2011), which is contrary to the universal markedness condition.

In this sense, researchers recently have claimed that segmental markedness is not the only phonological factor involved in coda development and that children are sensitive to phonological frequency in the target language (Zamuner, 2003). In general, less marked and more frequent patterns coincide but, all else being equal, children may produce marked structures early if these structures are frequent in their language (Rose, 2009). Under this view, for languages where obstruents are the most frequent codas, such as Dutch, English, Portuguese and French, it follows that obstruent codas will be acquired earlier than sonorant codas. Therefore, markedness and frequency taken together could be a good predictor of variability in phonological development (Demuth, 2011).

Syllable structure in Spanish

Spanish displays a preference for syllables with a consonant as an onset and a vowel in the nucleus position. CV is the most frequent syllable structure (56%). Complex rhymes are less frequent (30%), and are usually formed by a single consonant (CVC, *pan* 'bread'). On only very few occasions (0.16%) are rhymes formed of two consonants in word-medial position (CVCC, *constante* 'persevering') (Blaser, 2011). The distribution in Spanish Child-Directed Speech is similar (Roark & Demuth, 2000).

If syllables are analyzed by position, 47% of word-final syllables contain a coda, whereas only 28% of word-medial syllables do so in a corpus of 56,863 Spanish common nouns (Borràs-Comes & Prieto, 2013). Moreover, 47% of stressed syllables have a coda, although the percentage is very much higher for word-final stressed syllables (97%) than for word-medial stressed syllables (23%) (Lloyd & Schnitzer, 1967). Therefore, in the Spanish words that do have codas, codas are most likely to appear in word-final syllables, particularly in stressed word-final syllables.

Furthermore, there are not many studies on the frequency of Spanish codas by segment type, because authors tend to focus on absolute frequencies of all segments pooled together (Delattre, 1965; Lloyd & Schnitzer, 1967; Quilis & Esgueva, 1980; Rojo, 1991, Moreno Sandoval et al., 2006). Nevertheless, an approximation of the coda frequency by type of segment can be established in Spanish following the aforementioned authors. According to their data, the most frequent coda is fricative /s/, followed by nasal /n/, lateral /l/, and finally rhotic /ɾ/.

Moreover, there are phonological restrictions related to the distribution of codas (Delattre, 1965). In terms of place of articulation, the majority of codas in Spanish are coronals: three coronal sonorants (/n, l, ɾ/) and one coronal obstruent (/s/) are permitted in medial and final position, in both stressed and unstressed syllables (see Table 1).

Table 1. Distribution of Spanish codas by syllable structure and segment

	Word-medial		1) Word-final	
	Unstressed syllable	Stressed syllable	Unstressed syllable	Stress
n	*manzana* [man.'θa.na] 'apple'	*naranja* [na.'ɾan.xa] 'orange'	*joven* ['xo.βen] 'young'	*camió*
l	*calcetín* [kal.θe.'tin] 'sock'	*alto* ['al.to] 'tall'	*árbol* ['aɾ.βol] 'tree'	*carac*
ɾ	*tortuga* [toɾ.'tu.ɣa] 'tutle'	*barco* ['baɾ.ko] 'ship'	*azúcar* [a.'θu.kaɾ] 'sugar'	*yogur*
s	*estrella* [es.'tɾe.ʝa] 'star'	*pista* ['pis.ta] 'track'	*paraguas* [pa.'ɾa.ɣwas] 'umbrella'	*autob*

Moreover, there are two less frequent coronal codas (/d/ and /θ/), restricted by position (*admitir* [ad.mi.'tiɾ] 'accept', *verdad* [beɾ.'ðað] 'truth', *luz ['lu*θ*]* 'light'). However, their phonetic realization depends on dialectal distribution: contrary to the situation in Southern Spain and South America, in Northern European Spanish coda weakening does not take place and the differences between /d/ and /θ/ are neutralised (Real Academia de la Lengua Española [RAE], 2011). Furthermore, there are two non-coronal obstruent codas in medial position (/p/ *apto* ['ap.to] 'capable', and /k/ *acto* ['ak.to] 'act'), but non-coronal obstruent codas, and complex codas, as in *obstinando* [oβs.ti.'na.ðo] ('stubborn'), occur very rarely in the young child's vocabulary (Lleó et al., 2003). For all these reasons, these codas are not considered in the current study.

Therefore, nasals /n/, laterals /l/, rhotics /ɾ/, and fricatives (/s/) are the codas found in Northern Spanish children's productive vocabulary before the age of 3, and they are the target codas of the current study. The purpose of this paper is to explore their development further. In particular, coda accuracy is analyzed in relation to word position, stress, and type of segment.

Methodology

Data collection

We present a longitudinal study of two monolingual Northern European Spanish children, pseudonymized M (a boy) and A (a girl).[4] The sessions took place at the children's homes, during children free-play with their parents or their daily activities (e.g. bath). Both M and A were recorded at a sampling rate of 44.100 Hz with a quantization of 16 bits. Additionally, video recordings were made of A. In the case of M, monthly recordings last 60 minutes and in the case of A, 45 minutes. There are no recordings of A at the ages of 1;8 and 2;4.

The study lasted 12 months, beginning with the production of the first codas at 1;7 years old and ending at 2;7 years of age, when the children produced most of the codas. The analysis comprises 20.5 hours of M's recordings and 8 hours of A's, totalling 7069 utterances for M and 2716 for A. Out of the total of 9785 utterances, 8517 intended codas (tokens) were analysed: 6399 for M and 2118 for A. The exact number of codas by session is summarized in Table 2.

Table 2. Number of codas (tokens) produced by each child from 1;7 to 2;7

[4] M's transcriptions are available in CHILDES as *Aguirre's corpus*: http://childes.psy.cmu.edu, and A's are forthcoming in Phonbank.

	Age	1;7	1;8	1;9	1;10	1;11	2;0	2;1	2;2	2;3	2;4	2;5	2;6	2;7	Total
M	Production	2	32	126	38	71	146	62	108	655	666	431	537	550	
	Substitution	2	13	19	22	43	147	41	143	142	85	43	87	91	
	Deletion	86	256	354	264	270	235	61	79	199	124	81	50	38	
	Total	90	301	499	324	384	528	164	330	996	875	555	674	679	6399
A	Production	13	--	8	27	36	11	24	50	90	--	205	120	319	
	Substitution	0	--	0	0	6	0	0	4	0	--	13	1	2	
	Deletion	53	--	109	165	162	63	188	110	180	--	53	32	74	
	Total	66	--	117	192	204	74	212	164	270	--	271	153	395	2118

Data analysis

Phonetic transcriptions were made manually using Phon (Rose et al., 2006), a program designed to work on phonological acquisition, and checked with a second transcriber. When the transcribers did not agree, the transcriptions were not used. Agreement was reached for 95% of the data.

We analyzed only spontaneous data. Imitations of adult speech were excluded, because they can be phonologically more advanced than spontaneous speech (Zamuner et al., 2004). Glottal stops were not considered as codas (i.e. [ma.'maʔ] *mamá* ‘mum’), but glides ([w, j]) and aspirations ([h]) were counted as coda elements (Lleó, 2003). The expression *A ver* ‘let’s see’, and articles (*el, un*, ‘the’, ‘a’) were excluded. Both lexical and suffixal codas were included in the analysis[5]. The quality of vowels in the rhyme was not taken into account in the analysis of the subsequent coda.

The statistical analysis was done using SPSS. The dependent variable is coda production/substitution/deletion, and fixed factors are coda position in the word (medial or final), syllable stress (stressed or unstressed), and type of coda segment (nasal, lateral, rhotic, or fricative). Phi and V Cramer were calculated. Variables were

[5] It is important to point that before the age of 2 children did not produce morphological suffixes or at least they were not considered morphologically productive (Aguirre, 2003).

normalized in a Zscore statistic to calculate an ANOVA for comparing among segments. ANOVAs were used to establish the effect of fixed factors. Data were analyzed separately by child and results are presented monthly. Moreover, the substitution of phonemes in coda position was analysed and the frequency of the target language was taken into account in the discussion.

Results

Codas develop gradually in Spanish, as expected. In this corpus, M produces 4.4% (4 of 90: 2 accurate codas and 2 substituted codas) of total codas at 1;7 and A 19.7% (13 of 66: all accurate codas). At 2 years M produces 55.5% (293 of 528: 146 accurate codas and 147 substituted codas) and A 14.9% (11 of 74: all accurate codas). At 2;7 M produces 94.5% (641 of 679: 550 accurate codas and 91 substituted codas) and A 81.93% (321 of 395: 319 accurate codas and 2 substituted codas). However, M displays a bit of a jump between 1;11 and 2;0 and A between 2;3 and 2;5. As Table 2 shows, M shows higher production percentages of codas than A, but A's production is target-like whereas M's production shows a higher rate of substitutions. The following sections show the development of codas analyzed by factors.

Factor 1: Word position (medial and final codas)

When the production of medial and final codas is compared (see Table 3), there are statistically significant differences in M's production in 8 of the 12 months: at 1;8, at 1;10, and from 2;2 onwards. Word-final codas are produced more frequently, and the substitution rate is higher, in word-final position than in word-medial position before the age of 2;2 (see Figures 1 and 2). However, M produces more codas, and more accurate codas, in medial than in final position from the age of 2;2 onwards (see Figures 1 and 2).

Table 3. Comparisons between medial and final coda accurate production, substitution and deletion in each child

Statistical differences by position (medial/final)		1;7	1;8	1;9	1;10	1;11	2;0	2;1	2;2	2;3	2;4	2;5	2;6	2;7
M	Phi/V Cramer	0.183	0.365	0.153	0.187	0.025	0.047	0.157	0.270	0.178	0.127	0.185	0.166	0.126
	p value	0.221	0.001	0.30	0.003	0.887	0.565	0.133	0.001	0.001	0.001	0.001	0.001	0.004
A	Phi/V Cramer	0.338		0.172	0.029	0.115	0.114	0.161	0.274	0.049		0.253	0.102	0.045
	p value	0.006		0.063	0.69	0.259	0.327	0.019	0.001	0.424		0.001	0.453	0.676

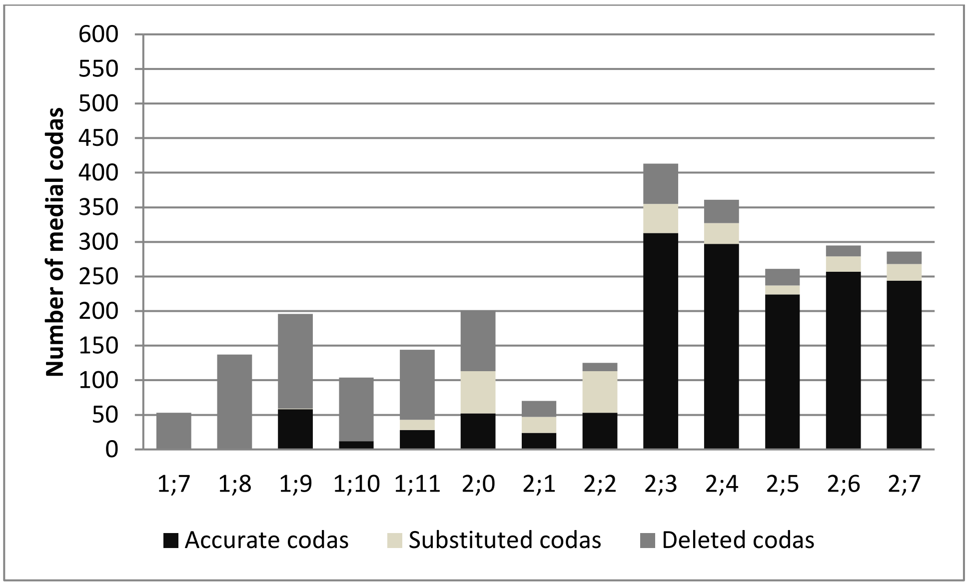

Figure 1. M's medial coda production

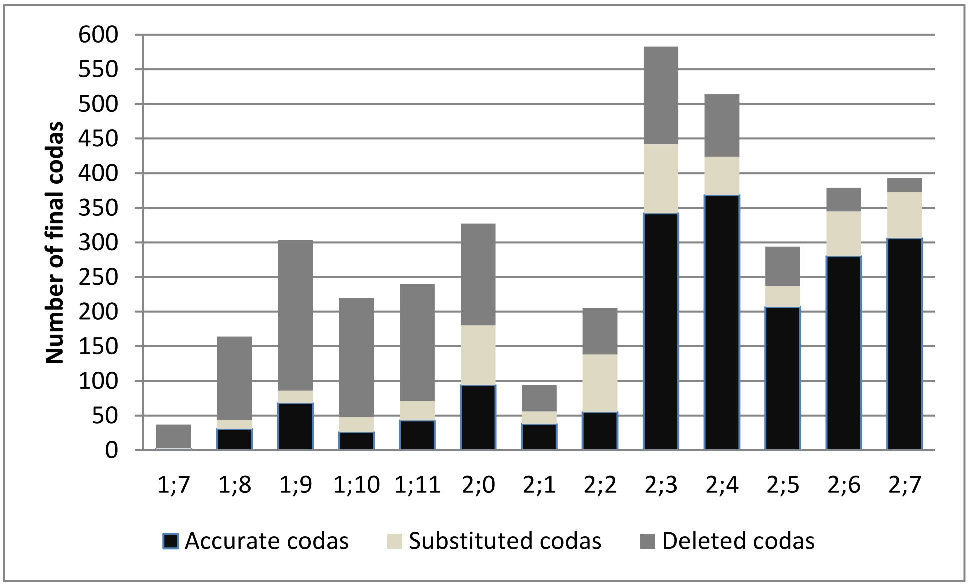

Figure 2. M's final coda production

In the case of A, there are statistically significant differences by position in only 4 of the months (see Table 3). A produces more codas in medial position than in final position at 1;7 (34% vs. 9.5%), and after 2;1 (17% vs. 6.8%), 2;2 (43.8% vs. 17.6%) and 2;5 (89.7% vv. 73.4%) (Figures 3 and 4). After 2;6 years old, there are no differences by position, since production is nearly target-like.

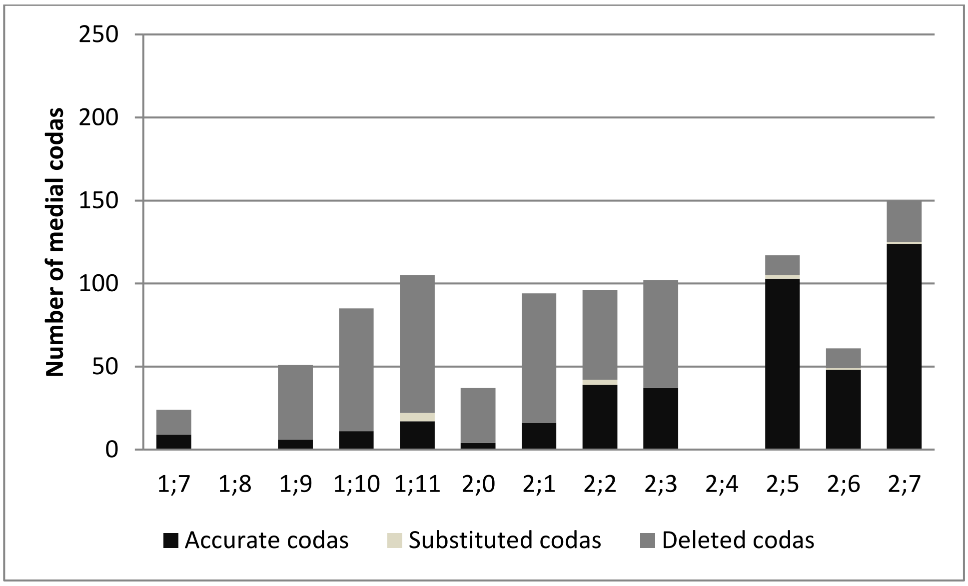

Figure 3. A's medial coda production

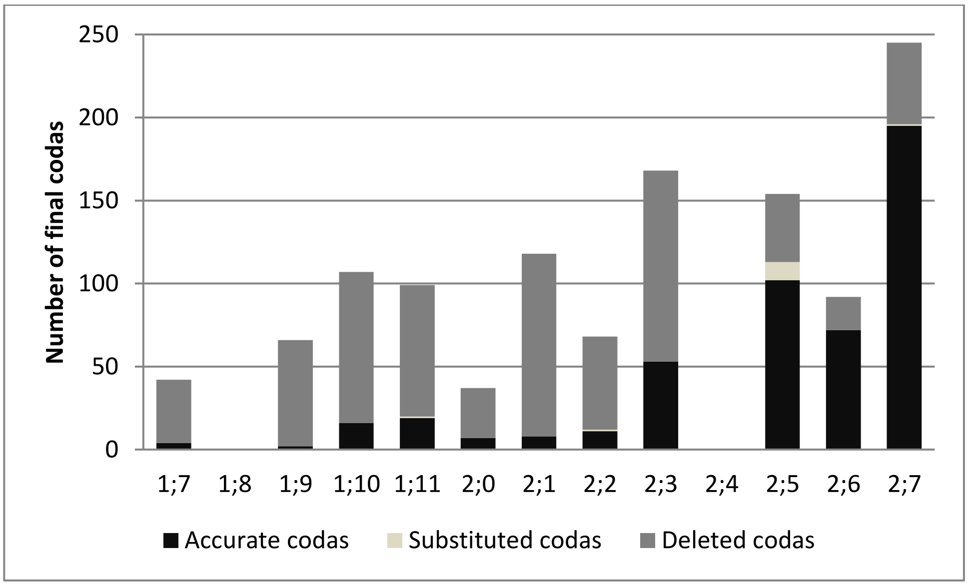

Figure 4. A's final coda production

In sum, M produces more codas in final compared to medial position before the age of 2. However, after the age of 2, both children produce more codas in medial position than in final position. M substitutes codas in both positions, but substitutions are more frequent in final position because this is where M is attempting more codas. By contrast, A produces very few substitutions, in either position.

Factor 2: Stress (codas in stressed and unstressed syllables)

Figures 5 and 6 show that until 2;2 years of age, M produces significantly more codas in stressed syllables. Moreover, accuracy is higher in stressed position since there are more coda substitutions in unstressed position than in stressed position up until 2;2. After 2;4, production is similar in both stressed and unstressed syllables, when percentages of production are higher than 80% in both cases. As Table 4 shows, differences are statistically significant over the production of codas in stressed syllables.

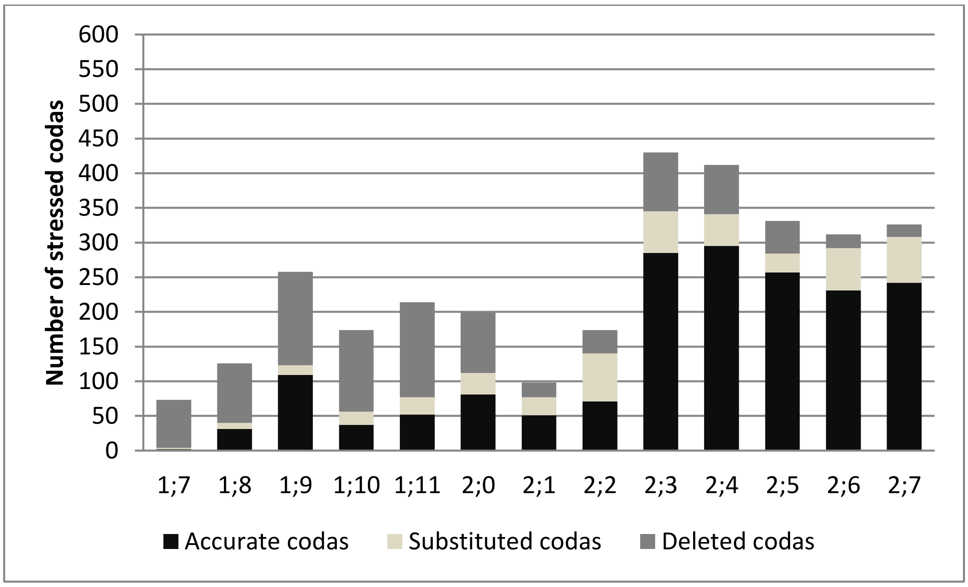

Figure 5. M's stressed coda production

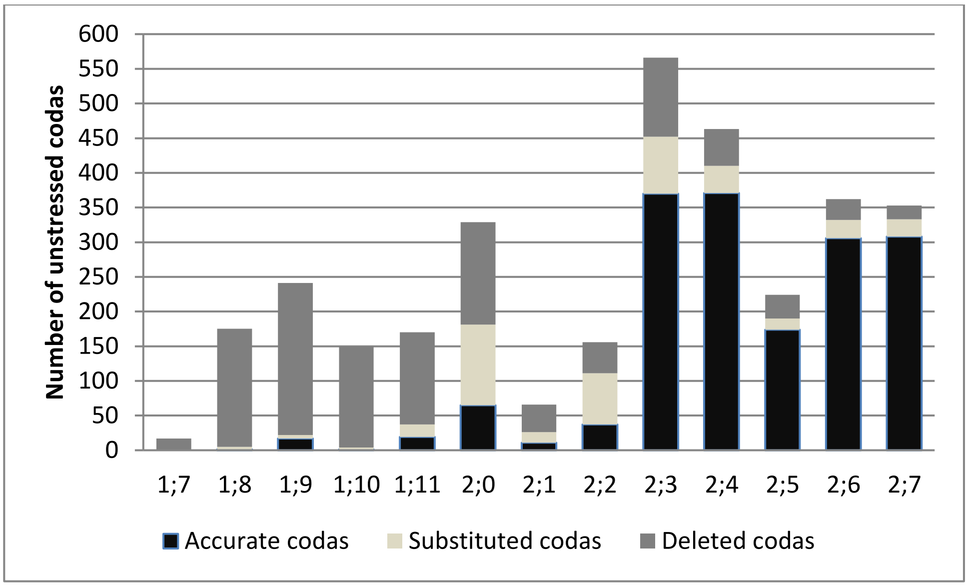

Figure 6. M's unstressed coda production

Table 4. Comparisons between stressed and unstressed coda accurate production, substitution and deletion in each child

Statistical differences by stress condition (stressed/unstressed)		1;7	1;8	1;9	1;10	1;11	2;0	2;1	2;2	2;3	2;4	2;5	2;6	2;7
M	Phi/V Cramer	0.104	0.412	0.427	0.382	0.174	0.265	0.425	0.186	0.010	0.101	0.022	0.185	0.194
	p value	0.614	0.001	0.001	0.001	0.003	0.001	0.001	0.003	0.953	0.012	0.876	0.001	0.001
A	Phi/V Cramer	0.313		0.142	0.255	0.267	0.201	0.126	0.107	0.089		0.290	0.234	0.084
	p value	0.011		0.123	0.001	0.001	0.084	0.066	0.394	0.143		0.001	0.015	0.252

Figures 7 and 8 show A's coda development in stressed and unstressed syllables. A produces significantly more stressed codas at 1;7, 1;10 and 1;11, and then again at 2;5 and 2;6.

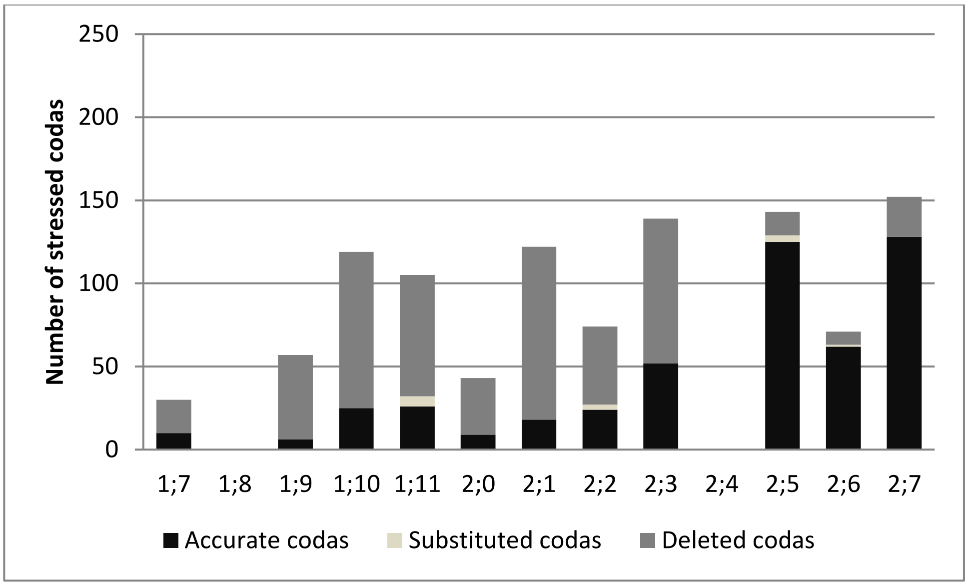

Figure 7. A's stressed coda production

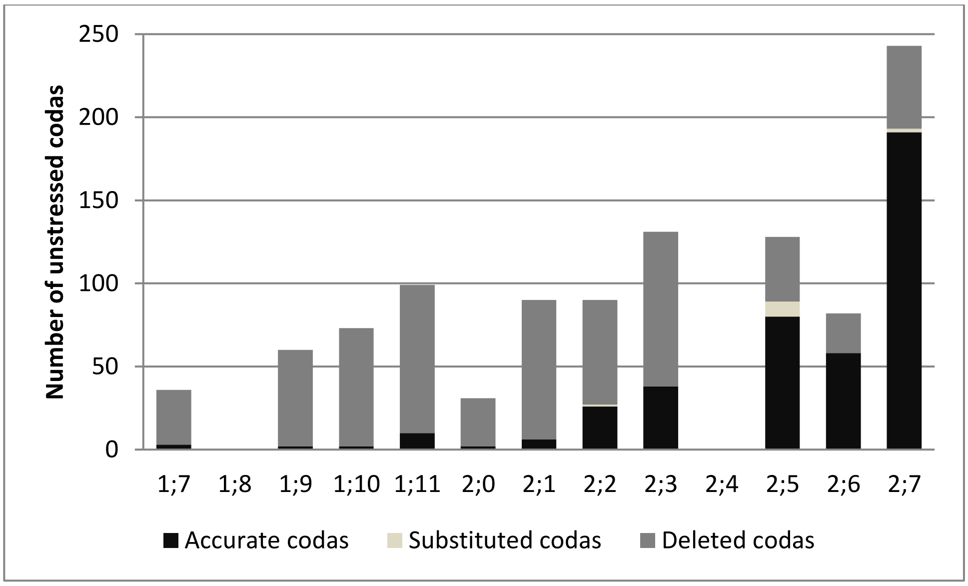

Figure 8. A's unstressed coda production

In sum, both children produce more codas in stressed syllables compared to unstressed syllables. M substitutes codas in both conditions, but after the age of 2 he substitutes more codas in unstressed syllables than in stressed syllables.

Factor 3: Type of segment (nasal, lateral, rhotic, and fricative codas)

For M, nasals are the first codas to be acquired: at 1;7 more than 50% of nasal codas are produced, reaching nearly 100% from 2;4 onwards. In each month, there are significant differences depending on the type of coda segment, except at 1;7 when the total number of codas is very low. Laterals do not exceed 50% until 2;2 years old, and fricatives pass the 50% mark at 2;0 years old. Before the age of 2, M produces more laterals than fricatives, but between 2;0 and 2;3 M produces more fricatives than laterals, and from 2;4, we observe the same production percentages for both segment classes. Rhotics achieve 50% production between 2;6 and 2;7. Therefore, nasals are the first coda segments to be produced, followed by laterals and fricatives together, and finally rhotics as Figure 9 shows.

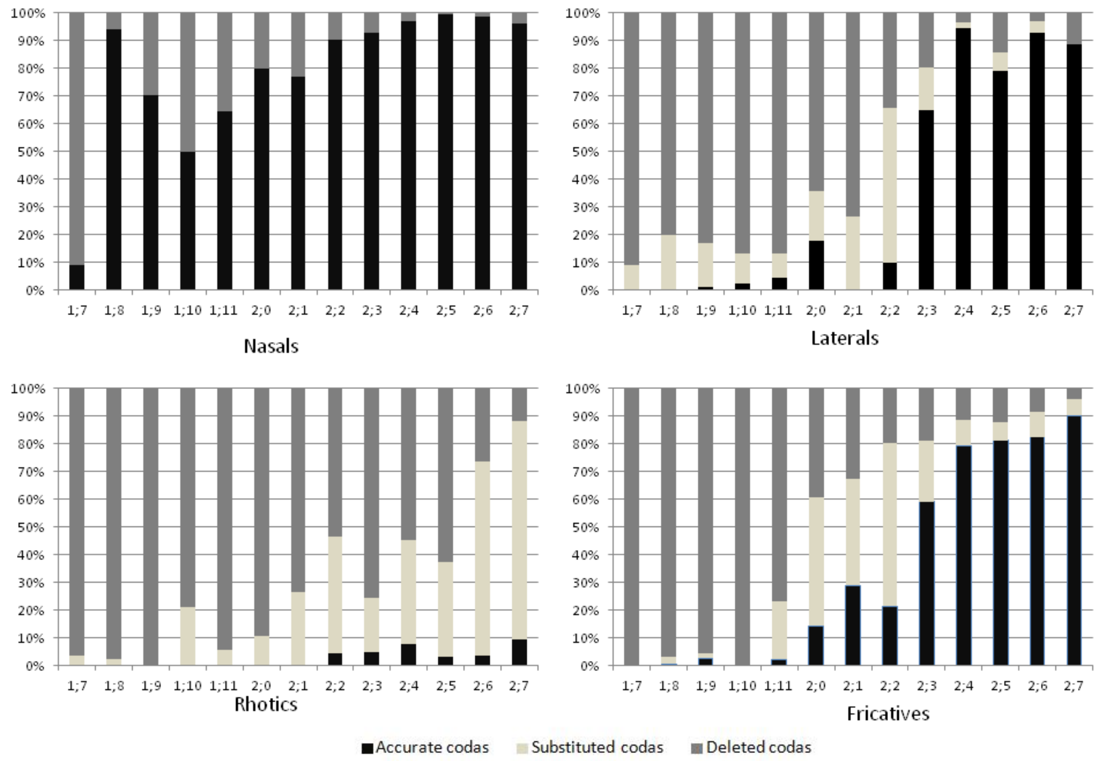

Figure 9. M's production accuracy by type of segment

Figure 10 shows that for A, nasals are also the first codas to be acquired: at 1;7 around 50% of nasal codas are produced, reaching nearly 100% from 2;4 onwards. Before the age of 2;3, production of laterals is less than 20% and that of fricatives is less than 10%. Rhotics do not show more than 50% of production at 2;7 years old, and before that age, no more than 30%.

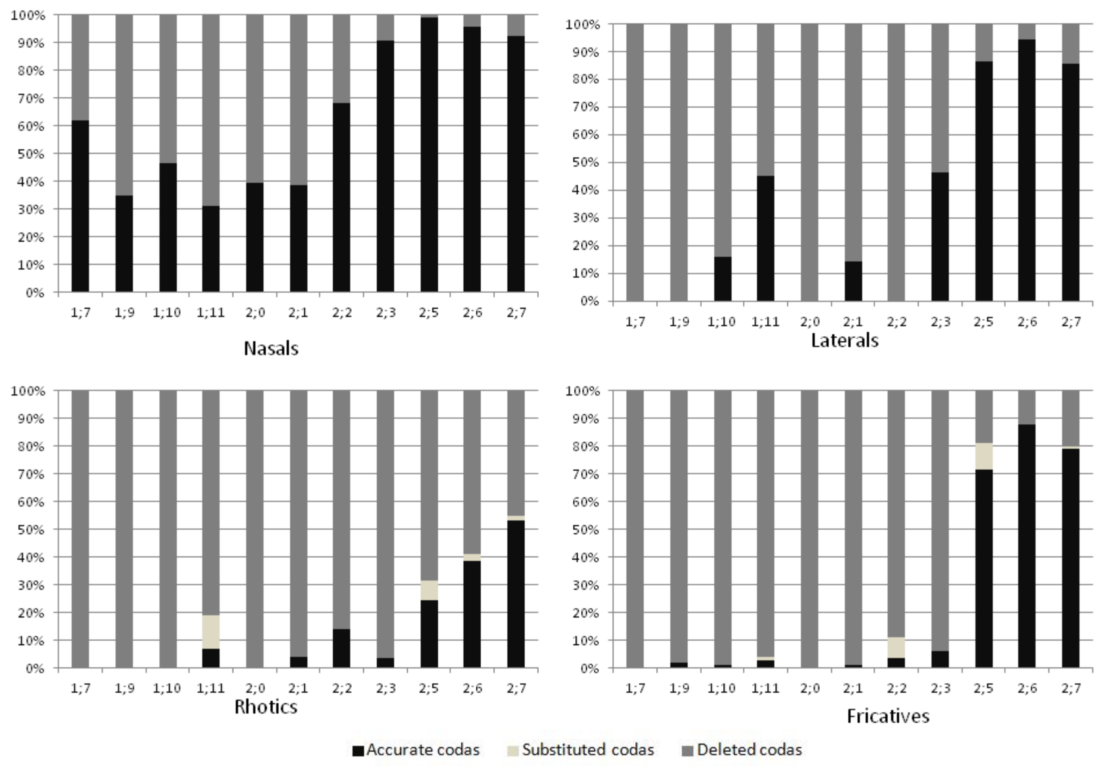

Figure 10. A's production accuracy by type of segment

In sum, both children first produce nasals in coda position, followed by laterals and fricatives, and finally rhotics. Although the difference between the production of laterals and fricatives is clearer for A, but there is very little difference for M: A produces very few fricatives until the age of 2;5, in contrast to the high number of fricatives in M's production. However, A's fricative coda production is more accurate than M's fricative production, as is explained in the due course.

Do factors influence each other?

To discover if an inter-subject effect exists across variables, a multifactorial ANOVA analysis was carried out. Zscore index was calculated to use dependent variables as continuous. For M, the analysis among factors shows an interaction between position and stress condition ($p = 0.003$), and between position and type of segment ($p < 0.001$), but not between stress condition and type of segment ($p = 0.076$). M produces more codas in stressed syllables in medial position ($p < 0.005$) (67%), but more unstressed codas in final position ($p < 0.005$) (51%). There are no differences in substitution rate since M shows more substituted codas in unstressed syllables independently of position (15%). M produces more nasals in medial position ($p < 0.005$), and he substitutes more laterals, where he produces more laterals, in medial position ($p < 0.005$) and more fricatives in final position ($p < 0.005$).

In the case of A's production, there is an interaction between stress condition and type of segment ($p < 0.001$), but not between position and stress condition ($p = 0.311$) or between position and type of segment ($p < 0.372$): A produces more lateral codas in stressed syllables ($p < 0.005$) and more fricative codas in unstressed syllables ($p < 0.005$).

In sum, these results mean that children acquire target-like codas earlier in medial word-position and stressed syllables (e.g. ‘CVC.CV), while the most difficult codas to produce accurately belong to unstressed and final syllables, where they show (especially in M's case) higher substitution rates. Substitution patterns are explained in the following section.

Coda substitutions

In the onset of speech development, coda substitutions are common among children (Demuth, 2011): In this period M produces more codas and substitutes more segments than A does. By contrast, we find that A barely substitutes codas and coda production is target-like from the onset of her productions. An analysis of substitutions was carried out by age, by position, by stress, and by type of segment.

Data from substitutions by position show that M substitutes 11% (292) of medial codas and 15.6% (586) of final codas in total; and produces 59.1% (1563) of medial codas and 49.6% (1861) of final codas accurately. The statistical analysis (Phi and V Cramer 0.098, $p < 0.001$) shows that position influences substitution in M's production, since M substitutes more codas in final position. As for the effect of stress, M produces more codas in stressed condition as explained above, but 20.7% of the 70.3% stressed total production is a substituted coda and in the unstressed condition 20.1% of the 64% total production is a substituted coda. The statistical analysis (Phi and V Cramer 0.065, $p < 0.001$) shows that stress influences M's production: M produces more codas in stressed syllables, but the substitution rate is higher in unstressed syllables than in stressed syllables. A substitutes codas very rarely overall: 1.3% (12) of medial codas and 1.2% (14) of final codas and there are no significant differences by word position (Phi and V Cramer 0.073, $p = 0.786$). A substitutes 1.3% (14) of stressed codas and 1.1% (12) of unstressed codas and this difference is not significant (Phi and V Cramer, 0.069, $p = 0.989$).

To summarize, M substitutes more codas in word final than in word medial position and in unstressed syllables compared to stressed syllables. A produces very few substitutions and does not show any preference in the substitution patterns, either by position or by stress.

An analysis of accuracy in M's coda production by type of segments, see Figure 11, shows that nasals, when realized, are always produced target-like, followed by fricatives and laterals. Correct fricatives constitute 48% and correct laterals 44.7% of tokens, while substituted fricatives constitute 17.3% and substituted laterals 13.1% of tokens; a series of Bonferroni-adjusted post hoc tests shows that laterals and fricatives behave similarly ($p = 1$). The most difficult segments to acquire are rhotics, which in this period are substituted in 32.5% of tokens and produced target-like in only 3.6% of tokens.

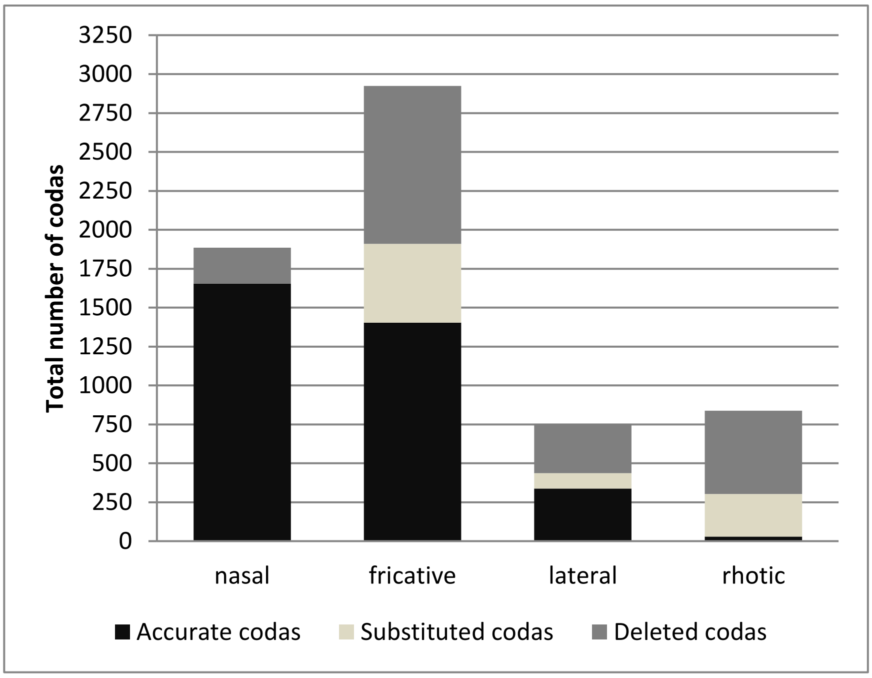

Figure 11. M's coda substitutions by type of segment

An analysis of the accuracy of A's coda production, see Figure 12, shows that nasals, when realized, are mostly produced target-like (72.4%), followed by laterals (44.4%) and fricatives (30.3%); substituted fricatives constitute only 1.9% of fricative tokens and there are no cases of substituted laterals. Zscore ANOVA [$F (3, 1) = 174.952$, p <

0.001] and Bonferroni-adjusted post hoc tests show significant differences in all segment groups ($p < 0.001$). The most difficult segment to acquire is the rhotic segment, which in this period is produced target-like (17.8%), but only 2.6% substituted.

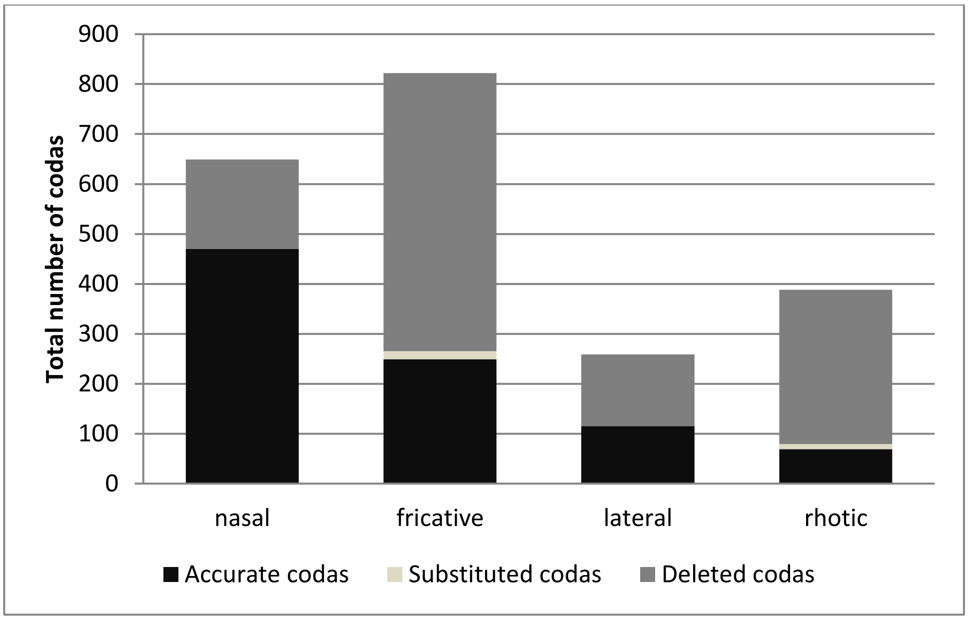

Figure 12. A's coda substitutions by type of segment

To summarize, nasals are always produced target-like, M substitutes laterals and fricatives less than 20% and both children produce very few rhotics, but A produces them with a higher degree of accuracy than M, who substitutes them in around 30% of tokens. These results indicate that nasals are easy to acquire and rhotics are difficult. M produces more fricatives than laterals, but target-like laterals are acquired before fricatives since the substitution rate in fricatives is higher than in laterals.

If we take a detailed look to the type of substitutions described above, most of M's lateral substitutions (A does not substitute laterals) are with a glide [j] (62%), followed by substitutions with a nasal (26%), and some kind of aspiration or friction

(9%), and nearly 1% of substitutions with a stop [p] or [t] (e.g. [ˈbop.pa] instead of [ˈbol.sa] *bolsa* ‘bag’ at 1;7 and [ˈbot.sa] instead of [ˈbol.sa] *bolsa* ‘bag’ at 2;2) (see Table 5). The first substitutions of laterals with nasals occur between 1;8 and 1;10 (e.g., [ta.ˈton] instead of [ka.ɾa.ˈkol], *caracol* ‘snail’) and after that age, these substitutions practically disappear. Substitutions with aspirations occur only during a very short period of time between 2;2 and 2;3 (e.g. [sah.ˈti.to] instead of [sal.ˈti.to], *saltito* ‘little jump’). Substitutions with a glide are the most common ones after 1;10 (e.g. [kaj.çe.ˈtin] instead of [kal.θe.ˈtin] (‘socks’). This pattern of substitutions for laterals according to segment type is not affected by word position or stress, indicating that the effect is robust across phonological contexts.

Table 5. M’s lateral coda substitutions

M	1;7	1;8	1;9	1;10	1;11	2;0	2;1	2;2	2;3	2;4	2;5	2;6	2;7	Total
l ↔ h	0	0	0	0	0	0	0	6	3	0	0	0	0	9 (9%)
l ↔ j	0	0	3	3	4	15	4	16	12	2	3	0	0	62 (62%)
l ↔ n	0	7	13	2	0	0	0	0	0	0	1	1	0	24 (26%)

Fricative substitutions are scarce for A, as Table 6 shows, and they appear after 2;2 years old when fricative coda production increases. In terms of the types of replacing segments, A has 18% substitutions with a glide [j] at 2;5 years old, but in most cases (82%), these substitutions are with aspiration [h]. Fricative substitutions for M are more frequent and present more variation than for A. The most common pattern for M is to substitute /s/ with a fricative that has a different place of articulation: 77% are aspirations, 13% are palatalizations, 4% are velarizations and 6% are substitutions with a glide [j]. The first fricative substitutions in M’s production are with a glide [j] at 1;8 (e.g. [ej.ˈpu.ma] instead of [es.ˈpu.ma] *espuma* ‘foam’). At 1;11, substitutions with aspiration start to be present in his production ([eh.ˈte.ja] instead of [es.ˈtre.ʎa], *estrella* ‘star’ at 2;6), at 2;0 velarizations ([mox.ˈki.to] instead of [mos.ˈki.to], *mosquito* ‘mosquito’), and at 2;1 palatalizations ([ˈpiç] instead of [ˈpis], *pis* ‘piss’). According to these results, it seems that the child acquires first manner of articulation (fricative) but has difficulties with the place of articulation of the sound, given the frequent changes in place but not in manner that are observed. This pattern is not affected by word position or stress for either child, indicating its robustness.

Table 6. Both children’s fricative coda substitutions

A	1;7	1;8	1;9	1;10	1;11	2;0	2;1	2;2	2;3	2;4	2;5	2;6	2;7	Total
s ↔ h	0		0	0	0	0	0	4	0		9	0	1	14(82%)
s ↔ j	0		0	0	0	0	0	0	0		3	0	0	3(18%)
M	1;7	1;8	1;9	1;10	1;11	2;0	2;1	2;2	2;3	2;4	2;5	2;6	2;7	
s ↔ h	0	0	0	0	25	119	23	59	92	30	15	19	15	397(77%)
s ↔ ç	0	0	0	0	0	0	9	42	14	2	1	0	0	64(13%)
s ↔ x	0	0	0	0	0	2	0	8	4	0	0	5	0	19(4%)
s ↔ j	0	5	2	0	10	4	1	2	1	2	1	2	1	31(6%)

Finally, coda rhotics are the segments that show the highest degree of substitutions and the most varied realizations by both children. A produces aspiration [h] or friction [ʁ] (62%) (e.g. [pin.ˈtah] instead of [pin.ˈtaɾ] *pintar* ‘to draw’ at 2;7); the next most frequent substitution is with the other liquid segment [l] in 24% (e.g. [ˈbel.ðe] instead of [ˈbeɾ.ðe] *verde* ‘green’ at 1;11); followed by substitutions with a glide [j] in 9% (e.g. [me.ˈtej] instead of [me.ˈteɾ] *meter* ‘get into’ at 2;2) and the least frequent ones are with the nasal [n] in 6%. In terms of when these substitutions appear, the substitutions are made with a lateral or a glide (1;11 and 2;2) and later with other segments, namely [h] at 2;5 and [n] at 2;7, as Table 7 shows.

As for coda rhotic substitution, M substitutes alveolar trill or tap rhotics with an alveolar approximant rhotic [ɹ] in 33%, followed by substitutions with the glide [j] in 27% (e.g. [ˈaj.βol] instead of [ˈaɾ.βol] *árbol* ‘tree’ at 2;4) and with aspiration or friction in 21% (e.g. [ka.ja.ˈmah] instead of [ka.la.ˈmaɾ] *calamar* ‘squid’ at 2;4). Substitutions with the glide [w] are 10%, with a nasal 8%, and with [l] only 1%. First rhotic substitutions are made by nasals at 1;10 years old. Substitutions with glides are preferred between 2;0 and 2;2. After 2;2, substitution with alveolar approximant [ɹ] appears, and after 2;4, no more substitutions with a nasal or lateral are reported. There are no differences by position or stress, but in both children a preference is observed for glides in medial position over other positions.

Table 7. Both children’s rhotic coda substitutions

A	1;7	1;8	1;9	1;10	1;11	2;0	2;1	2;2	2;3	2;4	2;5	2;6	2;7	Total
ɾ ↔ h	0		0	0	0	0	0	0	0		17	1	3	20(62%)
ɾ ↔ j	0		0	0	1	0	0	1	0		0	1	0	3(9%)
ɾ ↔ l	0		0	0	6	0	0	0	0		0	1	1	8(24%)
ɾ ↔ n	0		0	0	0	0	0	0	0		0	0	2	2(6%)
M	1;7	1;8	1;9	1;10	1;11	2;0	2;1	2;2	2;3	2;4	2;5	2;6	2;7	
ɾ ↔ h	1	0	0	0	0	0	0	0	1	13	9	15	14	53(21%)
ɾ ↔ j	0	0	0	0	4	6	1	7	3	17	4	18	14	74(27%)
ɾ ↔ l	0	0	0	0	0	0	0	1	1	1	0	0	0	3(1%)
ɾ ↔ n	0	1	0	17	0	0	3	0	0	1	0	0	0	22(8%)

ɾ ↔ w	0	0	0	0	0	0	0	0	2	13	1	6	5	27(10%)
ɾ ↔ ɹ	0	0	0	0	0	0	0	8	9	4	9	19	42	91(33%)

Figures 13 and 14 show that if substitutions are grouped according to the obstruent/sonorant distinction, rhotic and lateral codas are substituted with a sonorant segment, and fricative codas are substituted with obstruent segments, that is, sonorant codas are substituted with a sonorant, and obstruent codas are substituted with an obstruent.

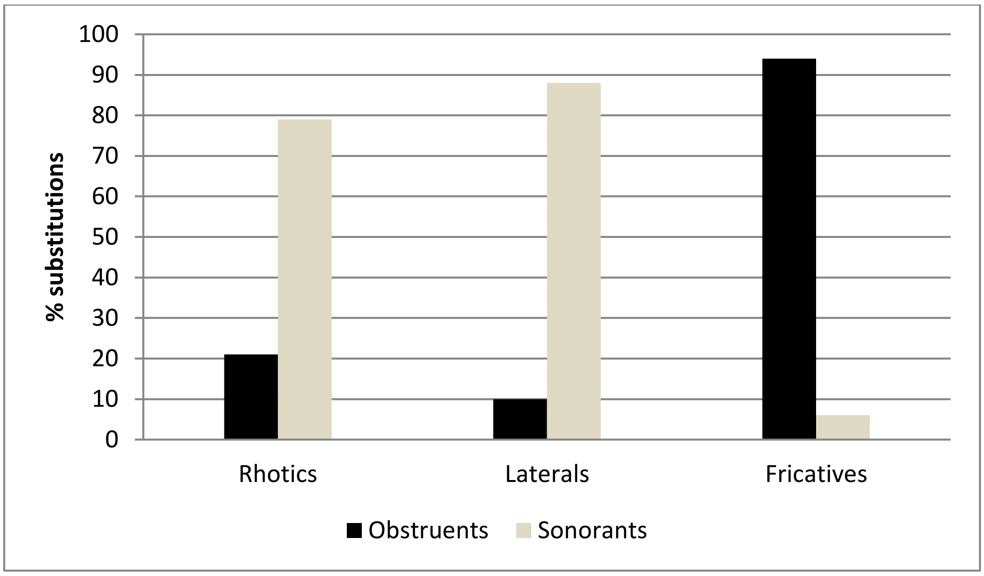

Figure 13. Type of substitutions for M

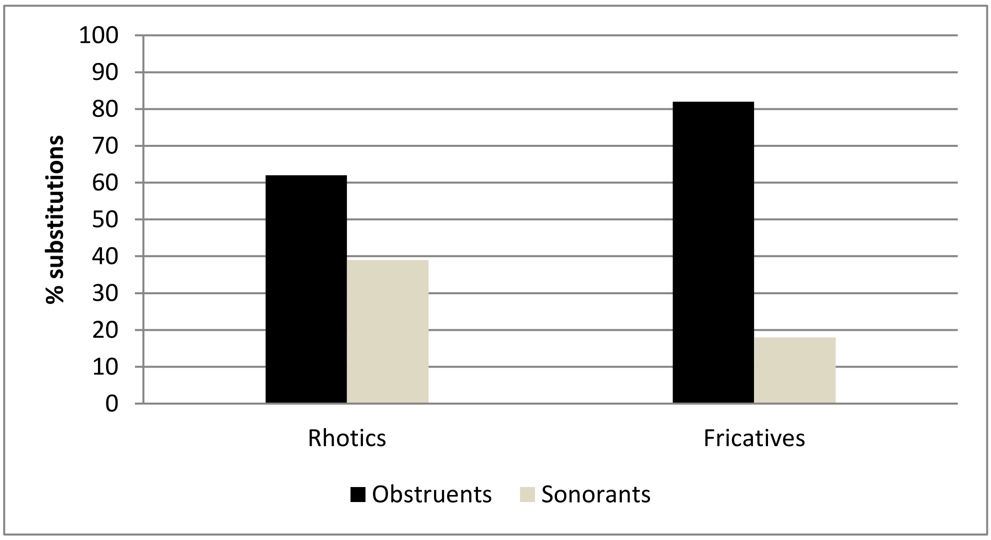

Figure 14. Type of substitutions for A

Discussion and conclusions

The present study provides a longitudinal exploration of coda development in two children acquiring Northern European Spanish from 1;7 to 2;7 years old, in which 8517 codas were analyzed. Both children perform as expected in Spanish (Carreira, 1991; Roark & Demuth, 2000; Lleó, 2002, 2003; Kehoe & Lleó, 2003; Lleó et al., 2003; Saceda Ulloa 2005). They show a gradual acquisition of complex syllables, in which only half of the codas are produced at 2 years old and coda acquisition is not fully completed at 2;7. However, M displays a bit of a jump between 1;11 and 2;0 and A between 2;3 and 2;5. To explain the differences in performance, beyond this overall pattern of coda acquisition, the current study explores the effect of different factors on coda development: the role of word position, stress, and type of segment have been analyzed, and particular attention has been paid to substitution patterns.

With respect to word position, M produces more codas in final compared to medial position before the age of 2 (except for nasals, which are mostly produced in medial position). However, after the age of 2, both children produce more codas in word medial position than in final position. Moreover, M acquires target-like codas first in medial position since after the age of 2 he is still substituting final codas. These results reflect the lack of consensus in the literature about the role of word position in coda production: some authors report that Spanish children prefer final codas (Oropeza Escobar, 2001), others argue that they produce more medial codas (Lleó, 2003), and yet other authors do not find any differences by word position (Nuñez-

Cedeño, 2007; although children in this study are bilingual). The present study shows that for these two children word final codas are preferred before 2 years old, following a universal pattern across languages, and after the age of 2 medial codas increase their production and their accuracy rate depending on Spanish syllable structure (Rose, 2003).

In relation to stress, authors argue that codas are universally acquired first in stressed syllables, since these are acoustically prominent positions which convey a positive effect on the production of coda consonants (Miles et al., 2016). This pattern has been reported previously for Spanish (Lleó, 2003; Saceda Ulloa, 2005), and is supported by the results of the current study: both children produced codas first and more accurately in stressed syllables. Furthermore, M shows more substitutions in unstressed syllables due to lower prominence of such syllables and the consequent difficulty of acquisition.

Taking stress and position together, children acquire target-like codas earlier in medial word-position and stressed syllables (‘CVC.CV). This word shape is very frequent in children’s first words in Spanish (Lleó, 2006). The most difficult codas to produce accurately belong to unstressed and final syllables.

Results regarding segment type show that nasals are the first segments to be accurately acquired and rhotics are not acquired until 2;7 years old, as other authors have found (Macken, 1978; Goldstein & Cintrón, 2001; Núñez-Cedeño, 2007; Fernández López, 2009; Borràs-Comes & Prieto, 2013). A produces more laterals, especially in stressed condition, than fricatives, especially in unstressed condition, and M produces more fricatives than laterals, but substitution rates in fricatives, especially in final position, are higher than in laterals. Therefore, laterals are acquired after nasals and before fricatives.

The most important finding of the present study relates to the patterns of coda substitutions. Some authors claim that children fill coda gaps with a glide ([w, j]) at the beginning of their acquisition of Spanish, but no more precise data about substitutions has been reported (Oropeza Escobar, 2001; Lleó et al., 2003; Morales-Front, 2006; Borràs-Comes & Prieto, 2013). The current study shows that stress and word position influence substitution patterns for both children: they substitute more codas in unstressed positions and in final position. These patterns are not affected by the type of segment for either child, indicating its robustness.

Nasals are produced accurately from the onset of production, and the most difficult segments to acquire are rhotics, which at 2;7 are barely produced target-like. There is a preference to substitute rhotics with glides in medial position. Fricatives are substituted more than laterals, even though fricatives are more frequent coda sounds than laterals in Spanish. Frequency does not help the accurate production of fricatives since, with lower frequency, laterals are easier to acquire. M first acquires manner of articulation (fricative) but has difficulties with the place of articulation of the sound. Fricatives are in fact marked sounds (Clements, 1990).

In terms of substitution patterns, the current study shows that sonorant codas (i.e. rhotics and laterals) are substituted with a sonorant, and obstruent codas (i.e. fricatives) are substituted with an obstruent, independently of syllable structure. This is an important finding because it can offer an explanation for children's substitution patterns: it shows that the substitutions are ordered, and that children substitute sounds with other sounds belonging to the same class of sounds that are being replaced.

As explained in the Introduction, frequency and markedness together could be a good predictor of variability in children language development (Demuth, 2011). In Spanish, final codas (Borràs-Comes & Prieto, 2013) and stressed codas (Lloyd & Schnitzer,

1967) are the most frequent codas and in fact salient conditions, and this is the pattern that acquisition follows: both children acquire stressed codas earlier and produce final codas before the age of 2. However, target-like codas are acquired in medial position first.

Markedness, if taken from a sonority standpoint, predicts that segments will be acquired in the order rhotics, laterals, nasals and fricatives. However, the most frequent codas in Spanish are fricatives, nasals, laterals, and rhotics in this order, and in fact, the acquisition order is nasals, laterals, fricatives, and rhotics. These results indicate that the high frequency of Spanish fricative codas (see Introduction) does help them to be produced earlier, but not as the first acquired segment as predicted, and their production is mostly substituted (especially in final and unstressed position).

To summarize, the most salient and frequent characteristics (i.e. stressed and word-final position) of Spanish complex syllables enhance coda development in the first stages of development. This indicates that the skeletal tier is the first to be developed in the early years, and only after its establishment do children focus on segmental quality, which will result in target-like acquisition of Spanish codas following markedness predictions: unmarked codas are acquired target-like earlier than marked codas (i.e. fricatives are marked). Rhotics can be an exception in terms of accuracy due to the complexity of articulating an alveolar trill in Spanish and other languages (Ota & Green, 2013). In summary, these results indicate that frequency and segmental markedness are both involved in Spanish coda development.

More work is needed to clear up coda development in Spanish, e.g. frequency vs. segmental markedness factors. It will be interesting to follow the A(rticulatory)-map model approach, as a hybrid explanation between formal and frequency models (McAllister Byun et al., 2016). This model has been illustrated with the acquisition of fricative onsets vs. fricative codas in Portuguese. Basically, children have two representational constraints, ACCURATE and PRECISE. The former will favour the production of a target-like coda, while the latter favours any coda whose associated motor plan maps reliably to a narrowly-defined acoustic goal region, i.e. a phone substitution. It would be interesting to analyze the development of Spanish codas under this hybrid view, because in this model phonology (e.g. distributions, stress) and phonetic factors (e.g. phonetic markedness) both contribute to explaining the developmental patterns, including inter-individual variation.

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Conflict of interest

There are not any conflicts of interest.

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