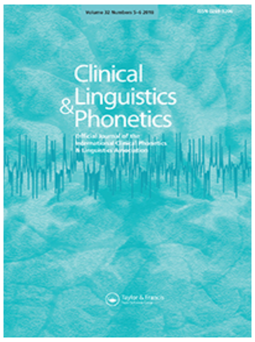

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Word-initial rhotic clusters in Spanish-speaking preschoolers in Chile and Granada, Spain

Denisse Perez[a], Pilar Vivar[b], Barbara May Bernhardt[c], Elvira Mendoza[d], Carmen Ávila[d], Gloria Carballo[d], Dolores Fresneda[d], Juana Muñoz[d], and Patricio Vergara[e]

[a]School of Speech-Language Pathology (Fonoaudología), University of Valparaíso, Valparaíso, Chile; [b]Faculty of Arts and Humanities, Temuco Catholic University, Temuco, Chile; [c]School of Audiology and Speech Sciences, University of British Columbia, Vancouver, Canada; [d]Faculty of Psychology, University of Granada, Granada, Spain; [e]Southern University of Chile, Valdivia, Chile

ABSTRACT

The current paper describes Spanish acquisition of rhotic onset clusters. Data are also provided on related singleton taps/trills and /l/ as a singleton and in clusters. Participants included 9 typically developing (TD) toddlers and 30 TD preschoolers in Chile, and 30 TD preschoolers and 29 with protracted phonological development (PPD) in Granada, Spain. Results showed age and developmental group effects. Preservation of cluster timing units preceded segmental accuracy, especially in stressed syllables. Tap clusters versus singleton trills were variable in order of mastery, some children mastering clusters first, and others, the trill. Rhotics were acquired later than /l/. In early development, mismatches (errors) involved primarily deletion of taps; where substitutions occurred, [j] frequently replaced tap. In later development, [l] more frequently replaced tap; where taps did occur, vowel epenthesis sometimes occurred. The data serve as a criterion reference database for onset cluster acquisition in Chilean and Granada Spanish.

KEYWORDS

Consonant clusters; lateral; mismatch patterns; protracted phonological development; Spanish dialects; typical phonological development

Introduction

As noted for many languages, rhotic clusters show later mastery in Spanish phonological acquisition (Bosch, 1984). In its contribution to the issue on rhotic cluster development in languages with tap or trill, the following paper uniquely reports data from two dialect areas: Chile and Granada, Spain. Although the focus is on word-initial (WI) rhotic clusters, data are also provided on related liquid targets to provide a context for the development of the clusters, i.e. singleton rhotics and /l/, both as a singleton and in clusters. Consistent with the rest of the issue, the current paper evaluates a number of potential influences on acquisition: age, developmental status (typical, TD or protracted phonological development, PPD), interactions of word structure (timing units, stress) and segment/features and specific segmental characteristics of the cluster sequences. (Readers are also directed to the introductory and concluding papers from this journal issue, which discuss the theoretical context for the individual data-based papers. See Stemberger and Bernhardt, 2017 and Bernhardt and Stemberger, 2017, in this issue) The data both serve to address the theoretical issues raised in the Introduction to the issue and to provide criterion reference data for Spanish.

CONTACT Barbara May Bernhardt bernharb@mail.ubc.ca 2177 Wesbrook Mall, University of British Columbia, Vancouver, BC. Canada, V6T, 1Z3.

The organization of the paper is as follows. After a general introduction, the methods and results of each study are reported in turn. The first report describes acquisition of clusters in toddlers longitudinally from nine TD Chilean children aged 1;6–2;8 (semi-structured play-based spontaneous samples). Two cross-sectional studies (Chile; Granada) evaluate responses of children aged 3 to 5 years on the same single word elicitation task: the Chilean study reports results from 30 typically developing (TD) children and the Granada study results from 30 TD children and 29 with protracted phonological development (PPD). The following introduction outlines relevant phonological characteristics of the two dialects and reviews previous research in the topic area, ending with predictions for the study.

Spanish phonology

Word structure

Although Spanish words may have as many as 10 syllables, disyllables are most common (41.9%), followed by monosyllables (27.2%) and trisyllables (20.3%). There is generally only one stressed syllable per word (Quilis, 2009). Most disyllabic words are stress-initial (in this issue called *left-prominent* words), e.g. *bruja*, /ˈbɾu.{x/h}a/, 'witch' (Quilis, 1983: 75); three-syllables words can also be left-prominent, e.g. *pájaro* /ˈpa{x/h}aɾo/ 'bird'). Words with non-initial stress are also relatively frequent and can be stress-final, e.g. *dragón* /dɾa.ˈɣo(n)/ 'dragon' (*right-prominent*), or stress-internal, e.g. *primavera* /pɾimaˈβeɾa/ 'spring' (*centre-prominent*). (See Chapter 6, Bernhardt and Stemberger, 1998, for a discussion of prominence.)

Spanish syllables require a nucleus but onsets and codas are optional (Quilis, 2009).[1] Diconsonantal sequences can occur in onset (tautosyllabic) and triconsonantal sequences across syllable boundaries (heterosyllabic). Word initially, clusters include: /pɾ, bɾ, fɾ, tɾ, dɾ, kɾ, gɾ, pl, bl, fl, kl, gl/ (D´Introno, Del Teso, and Weston, 1995). Rare clusters, e.g. /tl/ and /dl/, appear in borrowings, e.g. *Tlacalula*, from indigenous languages (Alarcos Llorach, 1965).

Consonants and vowels (Table 1)

Similar to most dialects of Spanish, both Chilean and Granada Spanish include the following consonants: Unaspirated voiceless stops /p, t, k/, nasals /m, n,[2] ɲ/, voiceless fricatives /f, s, {x/h}/,[3] affricate /t͡ʃ/, and liquids /l, ɾ, r/. Approximant-like fricatives /β̞ ð̞ ɣ̞/ alternate with voiced 'stops' /b d g/, the former intervocalically, and the latter where a strong onset is required, generally after a pause, but with differences reflecting the specific context (Barlow, 2003; Eddington, 2011). Whether the base forms are approximants or voiced stops is a subject of debate (Barlow, 2003; Eddington, 2011; Harris, 1969). Furthermore, the coronal 'stop/approximant/fricative' may delete altogether, e.g. *nada* [na:].

In Spanish, the rhotics have the following general characteristics: (1) the dento-alveolar trilled /r/ appears in the following contexts: word initially as a singleton, intervocalically in certain words and as a word-medial (WM) onset after /n/, /l/, and also /s/; (2) the dento-alveolar tap /ɾ/ occurs in the following contexts: in onset clusters after stops and /f/ and as a singleton in codas and intervocalically in certain words. The lateral is a dento-alveolar

[1]Codas are optional in Granada, with either full deletion or appearance of [h]/[^{h}] (the latter for fricatives). Chile has a similar pattern for coda /s/.
[2][ŋ] occurs allophonically before velars.
[3]{ } indicates optional pronunciations.

Table 1. Spanish consonants.

	Labial		Coronal		Coronal-Dorsal	Dorsal
	Bilabial	Labiodental	Dento-alveolar	Palato-alveolar	Palatal	Velar {/Glottal}
Stop	p b		t d			k g
Nasal	m		n		ɲ	
Trill			r[a]			
Tap			ɾ			
Fricative		f	(θ), s[b]	(ʃ)[d] (ʒ)	ʝ[c]	{x/h}
Affricate					ʧ[d] d͡ʒ[c]	
Approximant/Glide					j[c]	w
Lateral				l	(ʎ)[c]	

[a]The [l] and [ɾ] can interchange in coda in Granada Spanish, and a medial liquid coda before a stop may surface as a geminate stop. The lateral and rhotics in Chilean Spanish vary slightly according to context (Sadowsky and Salamanca, 2011).
[b]Granada Spanish shows variation in use of /s/ versus /θ/ (*seseo* versus *ceceo*).
[c]In Chile and Granada, orthographic 'll' is pronounced as /ʝ/ (*yeísmo*) or word initially as [d͡ʒ]. /ʎ/ is restricted to regions of Northern Spain and the Americas (e.g. Bolivia).
[d]/ʧ/ may be pronounced [ʃ] or in Chile, as [tˢ] or another close variant (Sadowsky, 2015).

'light' /l/. Liquids vary slightly with context, i.e. devoicing in context of voiceless obstruents, slight backing or fronting, etc. (see e.g. Quilis, 2009; RAE, 2011; Sadowsky and Salamanca, 2011). Tap clusters often have a facilitatory transitional vocalic element of approximately the same duration as the tap between the first consonant and the tap (RAE, 2011, p. 242, sometimes called 'svarabhakti' vowels).

In Chilean and Granada Spanish, liquids and clusters often show the following additional characteristics (for further information on the dialects, see RAE, 2011; Sadowsky, 2015).

(1) Word medially, sequences with tap or /l/ may appear as geminates (*carne* [ˈkanne], [ˈkanːe]) or in Granada, with lengthening of the preceding vowel ([ˈkaːne]).
(2) Coda /ɾ/ and /l/ may interchange, especially in informal speech.
(3) In Chile /b/ may be pronounced as a labiodental, possibly affecting production of labial clusters.

Acquisition of liquids in Spanish

Previous research on acquisition of liquids is discussed below in terms of age, accuracy (match data) and mismatch (error) patterns. Relative to younger children, a few studies have examined rhotic cluster development in spontaneous speech data in toddlers, e.g.: (1) Lleó and Prinz (1996: Madrid), 4 children, longitudinally between 9 and 25 months; (2) Gómez Fernández (1997: Seville), 104 children, aged 1 to 6 years; Goldstein and Cinturón (2001: Puerto Rico), three children aged 1;10, 2;4, 2;5 (single sample recordings). In the Gómez Fernández (1997) study, target words containing liquid clusters most commonly appeared between 18 and 24 months, especially with /tɾ/ (e.g. *tren* 'train', *tres* 'three'), although with mismatch patterns affecting the cluster. All three studies report appearance of two-element clusters (Timing Unit Match)[4] with occasional Full Segmental Match for both consonants between age 1;0 and 2;0; for example, Gómez Fernández (1997) recorded some accurate productions for /tɾ/ and labial clusters /pl/,

[4]Timing Unit indicates the phonological timing slot for each segment in a word. Timing Units can be preserved with phones that match the adult target or substitutions, e.g. /kru(s)/ > [kju] is a Timing Unit Match because both elements of the cluster are present, even if the second is a substitution.

/{b/β̞}l), /fl/, /pɾ/. Relative to mismatches, reports describe full cluster deletion or more commonly, production of the first consonant only (as a Full Segmental Match or Timing Unit Match with substitution, i.e. C2 Deletion). Relative to rhotic versus lateral clusters, Goldstein and Cintrón (2001) observed twice as many C2 Deletions for those with rhotics (69%:31%). In Lleó and Prinz (1996), two participants showed frequent C2 Deletion, but the other two showed more C1 Deletion, notably for /fl/ and /{g/ɣ̞}l/. Gómez Fernández (1997) also observed occasional C1 Deletion for voiced onsets, e.g. for WI /{g/ɣ̞}ɾ/ and WM /{d/ð̞}ɾ/; however, the voiced onsets usually surfaced as [β̞ ð̞ ɣ̞] with or without C2 Deletion, and word medially often as geminates with C2 Deletion, i.e. [β̞β̞, ð̞ð̞, ɣ̞ɣ̞]. In that study, words with /{d/ð̞}ɾ/ targets appeared later than the others (2;6). When substitutions replaced the liquids, Gómez Fernández (1997) participants replaced the tap more frequently with [l] than [j], [j] commonly substituting for /l/. Goldstein and Cinturón also reported frequent use of [l] for tap, but also [ð̞] (but no substitutions for /l/). In summary, before age 3, some accurate clusters appeared. Regarding mismatches, C2 Deletion was common, but C1 Deletion was attested for clusters with voiced targets and /f/. Substitutions included frequent use of [l] for tap, but also [ð̞] and [j], the [j] more commonly appearing for /l/. Thus, substitutions for the rhotics and /l/ were similar, but consonant deletion, a word structure mismatch pattern, was more common in clusters.

Turning to the older preschool period (ages 3–6 years), studies have reported a gradual increase in mastery of liquid clusters, although with somewhat different orders of acquisition. For Chilean children, Vivar (2009) found that 80% of clusters showed Full Segmental Match by age 4;0, with /l/ clusters (especially /pl/ and /fl/) being more advanced than tap clusters (especially /{d/ð̞}ɾ/). Melgar de González (1976) reports a similar order of acquisition (more than 90% match): by 4;6, labial clusters /pl/ and /{b/β̞}l/; by 5;6, other labial clusters /fl/ and /{b/β̞}ɾ/, plus dorsal clusters /kl/, /kɾ/ and /{g/ɣ̞}ɾ/; and by 6;6, all but coronal /{d/ð̞}ɾ/. Bosch's (1984) study showed mastery of stop -/l/ clusters by age 4;0 (i.e. slightly earlier than Melgar), some tap clusters by 5;0 (i.e. slightly later than Melgar), and by 6;0, all but /kɾ/ and /{d/ð̞}ɾ/ (similar to Vivar, 2009). Miras Martínez (1992) found similar results for /l/-clusters at age 4;0 (Almería, Spain), i.e. 100% mastery except for /kl/ (94%), with mastery of all by age 5;0. Tap clusters appeared earlier, however, in that study, with 78% match for /kɾ/ up to 97% for /pɾ/ at age 4;0, and 97% match for /gɾ/ and /tɾ/ but 100% for all others by age 5;0. Gómez Fernández's (1997) study also showed more advanced results for older preschoolers than e.g. Bosch (1984): mastery of /kl/, /{b/β̞}l/ and /{d/ð̞}ɾ/ between ages 3 and 4, with the rest acquired by age 5;0. Because the Gómez Fernández study was based on spontaneous speech data, not all clusters appeared in all samples, however, reducing the comparability of specific clusters. In summary, /l/-clusters were generally acquired by age 4;0 and tap clusters by age 6;0 or 7;0 but sometimes earlier. Labial clusters were sometimes earliest-acquired, in these cases suggesting an influence of articulatory complexity, with the labial-liquid sequence perhaps being easier to produce than sequences involving two lingual consonants. The differences among studies in relative mastery timelines undoubtedly reflects sampling effects, e.g. number of participants, connected speech versus single words, transcription narrowness or words elicited. For example, studies sometimes conflated onset cluster data from WI and WM positions; e.g. in Vivar (2009), /{d/ð̞}r/, elicited only word medially, was reported to be later-acquired than the other targets, all of which were elicited word initially. None of the studies specifically examined possible effects of word length or syllable stress on cluster development.

Relative to mismatch patterns, the studies of older preschoolers show cluster reduction early on, with increasing realization of both cluster Timing Units, especially between ages 3 and 4 years (Bernhardt et al., 2015; Bosch, 1984; Diez-Itza and Martínez, 2004). When both Timing Units fail to surface, the liquid is typically missing (Bosch, 1984; Diez-Itza and Martínez, 2004; Gómez Fernández, 1997). Whereas C2 Deletion is reported to be frequent, especially in children under age 4 years (e.g. Bosch, 1984; Goldstein and Cintrón, 2001), other reports have shown C1 Deletion to be relatively common in certain clusters, e.g. /gl, fl, dɾ/ (Bosch, 1984; Lleó and Prinz, 1996; Gómez Fernández, 1997). C1 Deletion in these specific contexts might arise because of differences in relative sonority of the liquid compared with the initial consonant, i.e. the tap or /l/ being a stronger onset (in essence, more stop-like) than a preceding /f/, /g/ or /d/, the latter two often pronounced as approximants in running speech (Barlow, 2003; Eddington, 2011). When the mismatch involves substitution, other coronals often substitute for the tap, frequently [l] (Bosch, 1984; Goldstein and Cintrón, 2001) but also [j], which also commonly substitutes for /l/ (Bosch, 1984; Vivar and León, 2009). In summary, reports vary somewhat on the order of cluster acquisition, although there is more agreement on mismatch patterns. However, previous studies have not examined data from different dialect areas within one report nor specifically addressed possible interactions of segments/features and word structure. For example, studies have not compared development of targets in stressed versus unstressed contexts. Further, consonant clusters involve sequences of structural timing units which are independent of segmental content. Timing units have their own set of developmental constraints, i.e. the ability or inability to produce two consonantal timing units in a row independent of segmental content. Previous studies have not specifically discussed development of cluster timing units.

The current paper

The current paper begins to address gaps in the literature identified above by reporting data on acquisition of rhotic clusters for two relatively under studied dialect areas for Spanish (Chile and Granada, Spain). Comparative data are also provided for related targets, i.e. singleton rhotics and /l/ as a singleton and in clusters. Predictions were made concerning participant groups and phonological variables for developmental match and mismatch patterns.

Higher match (accuracy) levels were expected as follows:

(1) By age and for Granada, by developmental status (TD/PPD);
(2) In terms of word structure: (a) for singletons compared with clusters, at least for the lateral, with less clear predictions regarding the rhotics; (b) for cluster timing units compared with actual cluster consonants; and (c) for targets in WI stressed versus unstressed syllables; and
(3) By consonant type: For (a) /l/ versus rhotics; and (b) labial clusters.

For mismatches, the following were predicted:

(1) More deletion than substitution in: (a) early and protracted development; (b) clusters compared with singletons; and (c) WI unstressed versus stressed syllables.
(2) More deletion for: (a) single consonants than full clusters or syllables; (b) C2 than C1 (the latter occurring primarily for voiced C1 or /f/).
(3) Predominantly coronal substitutions, most often [l] but also [j] (and approximant [ð̞]).

Study 1: Chilean TD toddlers: Method and results

Method: Chilean toddlers

Participants

Following formal parental consent, nine monolingual Spanish toddlers in Concepción, Chile participated in a cross-sectional/longitudinal study. Children were divided into four age groups: 1;6–1;8 (Participant [P]1.1, P1.2, P1.3); 1;9–1;11 (P2.1, P2.2); 2;0–2;3 (P3.1, P3.2); 2;4–2;8 (P4.1, P4.2). Typicality of development was established through a questionnaire completed by their upper-middle class university-educated parents (*Cuestionario sobre la Interacción Communicativa Adulto-Niño*, Maggiolo and Martínez, 2005).

Procedures

A linguist and a speech-language pathologist collected the data jointly, primarily in the family's home but also in preschools. Each child was digitally audio-recorded two to three times per month over a 3–4 month period using a TASCAM DR-40 recorder with built-in microphone. Fifteen stories and 160 images served as stimuli in a semi-structured play context. (The young age of the children precluded the application of a standard naming test.) The second author transcribed the recordings using the International Phonetic Alphabet (IPA, International Phonetic Association, 2006), and entered the data into EXMARaLDA (Schmidt and Wörner, 2001). A linguist with expertise in child phonetic transcription consulted on the data, with over 90% agreement between transcribers.

Match (Full Segmental Match, Timing Unit Match) and mismatch analyses were conducted for spontaneous utterances (single words and connected speech). The major focus of analysis was onset cluster targets: 149 /l/ clusters and 244 /ɾ/ clusters (most WI) in total across all children. Singleton /l/ and rhotics, plus non-initial liquid cluster targets were also examined. In keeping with the theme for the volume, mismatch patterns are presented primarily for the rhotics, examining deletion (syllable, cluster, C1, C2), substitutions (C1, C2, C1C2) and other patterns, e.g. C1 Deletion *plus* C2 Substitution, metathesis, epenthesis, etc.). Data are presented descriptively only; inequalities in numbers of targets and heterogeneity of data preclude statistical analysis.

Results: Chilean toddlers

Match data are presented first (for rhotics and /l/), followed by mismatch data for rhotics. Supplemental information is presented on other word positions and /l/ because of the low numbers of WI tokens and reduced match levels for the lateral.

Match data: Chilean toddlers

Although the age range in the toddler study was relatively small, there was a small increase in Timing Unit Match in clusters as expected. However, liquids were still developing and rhotics in particular were marginal (see Tables 2 and 3).

The /ɾ/ clusters were emerging: Full Match: 7.6%; Timing Unit Match: 11.9%. (WM and WF singleton taps also were marginal.) As predicted, labial stop clusters had the highest match but /kl/ was also advanced. Clusters were ahead of the trill developmentally, the latter showing no accurate productions in this period. Also concerning segments, the comparison phoneme /l/ was

Table 2. Study 1, Chilean toddlers: Match and mismatch proportions for word-initial singleton /r/ and /l/ in stressed and unstressed syllables.

Segment/Context	Match proportions		Mismatch proportions and types			
/r/	0/42 (0%)		Stressed:		Unstressed:	
			Deletion	9/21	Deletion	16/21
			Substitution	12/21	Substitution	5/21
/l/ (content words)	29/58 (50%)		Stressed:		Unstressed:	
	Stressed	Unstresssed 9/29 (31%)	Deletion	20/25	Deletion	1/4
	20/29 (69%)		Substitution	5/25	Substitution	3/4
/l/ (articles)		Unstressed: 55/79 (69.6%)			Unstressed:	14/24
					Deletion	10/24
					Substitution	

Table 3. Study 1, Chilean toddlers: Percent Full Segmental Match for specific clusters.

/ɾ/-clusters						/l/-clusters				
Labial			Coronal		Dorsal	Labial			Dorsal	
pɾ	{b/β}ɾ	fɾ	tɾ	{d/ð̞}ɾ	{g/ɣ̞}ɾ	pl	bl	fl	kl	{g/ɣ̞}l
18.1 (2/11)	9.1 (2/22)	11.1 (1/9)	5.5 (8/137)	0 (0/20)	13.5 (5/37)	20.0 (8/40)	15.8 (3/19)	22.2 (4/18)	15 (3/20)	11.5 (6/52)

Note. Total match: Tap clusters = 7.6% (18/236); /l/-clusters = 16.1% (24/149).

in advance of the rhotics as expected: (1) /l/ clusters at 16.1% Full Segmental Match and 20.1% Timing Unit Match; and (2) singleton /l/ at 50% match in content words and 69.5% for unstressed article *la* ('the').

Mismatch data: Chilean toddlers (Tables 4–6; Figure 1)

Figure 1 displays frequencies of overall cluster mismatch types, and Table 4, substitution types in clusters.

As expected, the major mismatch pattern for tap clusters was C2 Deletion. In contrast to the cluster context, WM /ɾ/ showed equivalent levels of deletion and substitution (about 20%). The /dɾ/ cluster that did not undergo C2 Deletion but either full cluster deletion (22% of targets) or C1 Deletion *and* C2 Substitution; the latter combination pattern also occurred for other clusters with voiced initial consonants, i.e. /gɾ/, /bl/ and /gl/. C1 Deletion did not appear independently for tap clusters but did appear on occasion for each /l/ cluster. The /l/ and tap clusters showed somewhat different patterns, the former showing more equivalent levels of C2 Deletion, C2

Table 4. Study 1. Chilean toddlers: Rank-ordered substitutions for onset rhotics and /l/ in clusters and as singletons.

Target	3–12 substitutions	1–2 substitutions
Word-initial C/ɾ/	**j (12)**	ɰ, ʃ
Word-medial C/ɾ/	**j (13)**	l, t, m (2 each) > ʝ̞, k, ɣ
Word-initial /r/	**d (9)** > t, l, ʝ̞ (3 each)	ɣ, n, ɾ, t͡ʃ
Word-medial /r/	**ʝ̞ (8) > l (5)**	d (2) > t, ɣ, n, b
Word-medial /ɾ/	**d (12)** > **l (10)** > t (5) > ʝ̞ (4)	b (2) > ɣ, n, m
Word-initial C/l/	**j (15)** > **ɰ (6)**	
Word-medial C/l/	**j (9)**	
Word-initial /l/		
Word-medial /l/		n, ʝ̞ (2 each) > ɣ, h, t, d

Note. **Bolded and underlined** = most frequent. All word-medial targets were onset intervocalic onsets.

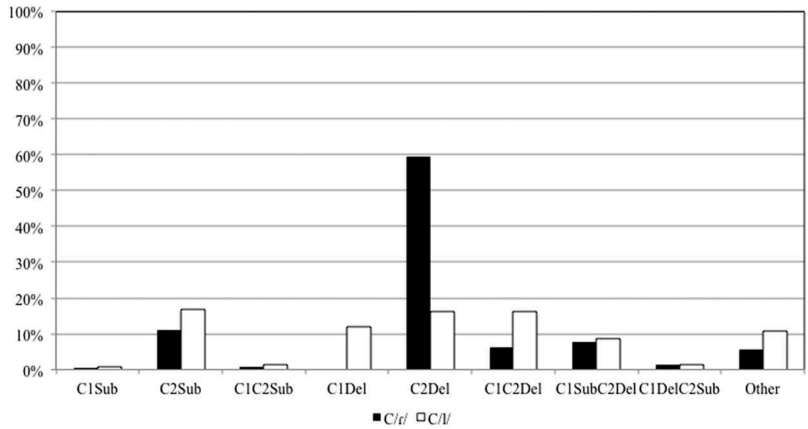

Figure 1. Study 1. Chilean toddlers: Mismatch pattern frequency over total targets for onset clusters (both word-initial and word-medial). C = consonant (number refers to position in the cluster); Del = deletion, Sub = substitution.

Substitution, C1C2 Deletion and C1 Deletion. The less common pattern of full cluster deletion appeared for all rhotic clusters except /pɾ/. One child (P1.2) showed full cluster deletion in every recording session, along with deletion of simple WI onsets, e.g. *jugo* /'xu.[ɣ]o/ > ['u.ɣo] 'juice'; *leche* /'le.t͡ʃe/ > ['e.te] 'milk'; /'bla[ŋ].ko/ > ['aŋ.ko] 'white'; *globo* /IPA go.bo/ > ['o.vo] 'balloon'. (See also Appendix 1.)

Among C2 substitutions, coronals were most frequent for both tap and /l/, primarily [j] although also [ɰ, ʃ] for the tap. In comparison, singleton WM tap surfaced as [d] or [l] most frequently. Along with [t], [l] and [j], [d] also commonly replaced the trill /r/, e.g. *ruedas* /'rueðas/ as ['de.daʰ] ('wheels') (P.1.1: reduplication). Infrequent substitutions for the trill included coronals tap and [t͡ʃ], other assimilations [n] (*rana*) and [ɣ] (*ruedas*). Word medially, similar substitutions occurred for trill, but there was a higher proportion of [j] and more deletion, e.g. *perro* ['pe.o] or ['pe.jo] (P.4.2); [l] occurred only sporadically. Tables 5 and 6 provide word examples of changes for the clusters over time. After the first 'stage' (C_1), characterized primarily by C2 Deletion, a second 'stage' emerged, with glide substitutions for C2 (C_1C_G), and a concomitant increase in Timing Unit Match. In the final 'stage', both consonants were present. Across children, there were different rates and routes of acquisition across clusters, following characteristics of each child's phonological system. A child might proceed through all "stages" for one cluster but skip a "stage" for another. For example:

Table 5. Study 1. Chilean toddlers: Examples, longitudinal mismatch changes in tap clusters.

				Age/Stage 1: C_1		Age/Stage 2: C_1C_G	
Participant	C1	Position	Target	Age	Production	Age	Production
P4.2	Labial	WM	sor.'pre.sa	2;6.4	so.'pe.sa		
	(p, b)		kom.'prar.la			2;9.5	kom.'pja.la
			som.'bre.ro	2;7.23	som.'be.jo		
			'li.bro			2;7.3	'li.bjo
	Coronal (tr)	WM	'o.tro	2;5.16	'o.to		
		WI	'tren			2;7.17	'tjen
P1.2	Coronal (tr)	WI	'tren	1;6.25	'teː	1;6.25	'tjen
P1.1		WI	'tren	1;9.11	'ten	1;19.25	'tjen
P2.2	Dorsal (gr)	WI	'{g/ɣ}ra.sjas	1;10.22	'ta.sja	1;11.17	'gja.sja

Note. WI = word-initial; WM = word-medial; P = participant.

Table 6. Study 1. Chilean toddlers: Examples of mismatch changes for onset /l/-clusters.

				Age/Stage 1: C_1		Age/Stage 2: C_1C_G	
Participant	C1 Type	Position	Word	Age	Child	Age	Child
P1.3	Dorsal (gl)	WI	/'{g/ɣ̞}lo{b/β̞}o (s)/*balloon(s)*	1;7.6	['βo.va]	1;8.1	['wa.ɣwa]
P3.1				2;3.13	['bo.bo]	2;4.27	['gwo.bo]
P2.2				1;9.23	['go.lo]	2;1.1	['gwo.boʃ]
	Labial (pl, bl, fl)	WI	/ˈblaŋ.ko/ *white*	1;10.22	[ˈtan.ta]		
		WM	/ˈa.bla/ *speaks*			1;11.17	[ˈam.bja]
P4.2		WI	/ˈpla.ta.no/ *banana*	2;4.28	[ˈpa.ta.no]		
			/ˈplan.ta/ *plant*			2;5.16	[ˈpjan.ta]
			/ˈflo.ɾes/ *flowers*	2;4.28	[ˈfo.le]	2;5.16	[ˈfjo.let͡ʃ]
		WI	/ˈblaŋ.ko/ *white*	2;4.6			[ˈbjaŋ.ko]
		WM	/om.ˈbli{g/ɣ̞}o/ *belly button*	2;6.4	[um.ˈbiɣo]		

Note. WI = word-initial; WM = word-medial; P = participant.

plátano /'pla.ta.no/ ('banana') as ['pa.ta.no] at 2;0.27, then *cumpleaños* /kum.ple.'a.ɲos/ as [kum.'pja.ɲo] ('birthday') at age 2;3,29; and finally *playa* /'pla.ʝa/ as ['pla.ʝa] ('beach') at age 2;6,5; but *globo/globito/* /'glo.b(it)o/ first as ['bo.bo], then [glo.'βi.to] ('balloon').

Summary: Chilean toddlers

In accordance with study predictions, match levels increased by age, structural and segmental complexity, even if the differences were small. That is, match scores were higher for the older toddlers, the less complex /l/ compared with rhotics, the less complex tap compared with trill, the less complex singleton versus cluster /l/ and labial clusters (although /kl/ was equivalent in match level to the labial clusters). For mismatches, as expected, consonant deletion was more frequent than full cluster deletion or syllable deletion, and C2 Deletion was a common mismatch pattern, more for rhotic than lateral clusters. C1 Deletion did occur on occasion for /dɾ/ and /gɾ/ as predicted (with C2 Substitution) but contrary to expectations, was also observed for each /l/ cluster. Although at low frequency, other patterns (metatheses, epentheses), including complex mismatch patterns, occurred, e.g. C1 Substitution *with* C2 Deletion. Substitution patterns showed somewhat expected developmental trends: coronals were frequent substitutions for rhotics, although the less expected glide [j] was the most frequent replacement of tap in clusters, and the stop [d] and palatal voiced fricative were more common for singleton trills. The [l] was a frequent substitution only for singleton tap word medially.

Study 2: Chilean TD preschoolers: Method and results

Method: Chilean preschoolers

Participants

Participants were 30 TD preschoolers (aged 3–5 years) from middle-high income families in Valparaíso, Chile recruited with informed parental written consent. Typicality of development was established through parent questionnaire, language tests and an oral mechanism examination: *Test de Articulación a la Repetición* (TAR: Schwalm, 1981); *Test para evaluar procesos de simplificación fonológica: Versión revisada* (TEPROSIF-R: Pávez, Maggiolo, and Coloma, 2008); *Test de Compresión Auditiva del Lenguaje* (TECAL: Pávez, 2004); *Test Exploratorio de Gramática Española de A. Toronto: Aplicación en Chile* (also known as the *Screening Test of Spanish*, STSG: Pávez, 2012); an adaptation of Prutting and Kirchner's (1987) pragmatic communication protocol and an oral mechanism test, Pauta de Evaluación de Órganos Fonoarticulatorios (adapted from Bustos, 1995).

Procedures

A native speaker of Chilean Spanish (speech-language pathologist) digitally audio-recorded each child's single-word responses to a 103-word picture naming task using a M-Audio *MicroTrack* II recorder with associated lapel microphone. Prior to the picture elicitation, the experimenter presented nine objects for naming, both as a warm-up task and to elicit more tokens of lower frequency targets in the sample. Sentence completion techniques ensured that most responses were spontaneous single words, but delayed or immediately imitated responses were accepted as needed.

The naming task probes all Spanish phonemes and key word structures.[5] Data extracted from that elicitation for the current study included 11 tap clusters, 6 /l/-clusters, and 4 singleton /r/s and /l/s each (Appendix 2). All words were transcribed using the IPA (2006), first by the second author, and then by an expert in phonetic transcription at the Universidad Austral de Chile, with 90% reliability for consonants and vowels without diacritics. PHON (Rose and MacWhinney, 2014) and spreadsheets supported quantitative analysis. Match (Full Segmental Match, Timing Unit Match) and mismatch analyses were conducted for rhotic and lateral singletons and clusters by age and developmental group. In addition, accuracy was compared in left versus centre and right-prominent words (stressed versus unstressed contexts). Mismatch patterns were evaluated for the rhotics, the main focus of the paper. Both parametric and nonparametric statistical tests were used to evaluate match data, the latter when homogeneity of variance was violated.

Results: Chilean preschoolers

Match and mismatch data are presented for the TD Chilean preschoolers in turn. Variables of interest were age, structural context (singleton/cluster; stressed/unstressed) and segmental types.

Match levels: Chilean preschoolers

The rhotics showed significant increases in accuracy by age as expected, specifically comparing ages of emergence at ages 3/4 versus mastery at age 5 (Table 7): Timing Unit Match – F (2, 27) = 12.234, p = .001, partial η^2 = .847 (large effect size); Full Match – F (2, 27) = 7.610, p = .002, partial η^2 = .36 (small effect size; Bonferroni-adjusted p levels were .01 for 3- versus 5-year-olds, and .005 for 4- versus 5-year-olds in tap cluster development for Full Match.) The comparison rhotic target, WI singleton trill, showed emergence at ages 3 and 4 years, and near-mastery (87.5%) at age 5, a significant change: F (2,27) = 16.428, p = .001, partial η^2 = .549 (moderate effect size).

[5]See *phonodevelopment.sites.olt.ubc.ca*, Test Materials/Spanish, for an updated version of the test.

Table 7. Percent Match Data for Chilean and Granada preschoolers for word-initial rhotics and laterals.

		Full Match						Timing Unit Match		
		/r/	/r/	C/r/	C/r/	/l/	C/l/	C/r/	C/r/	C/l/
Dialect	Group	LProm	CRProm	LProm	CRProm	LProm	LProm	LProm	CRProm	LProm
Chile	TD3yr	**10**	**10**	62.9	**40**	100	71.4	75.7	**43.3**	78.6
	TD4yr	**10**	**26.7**	**48.6**	**36.7**	90	82.9	81.4	**56.7**	88.6
	TD5yr	100	93.4	94.3	86.7	100	95.7	97.1	90	97.1
Granada	TD3yr	**44.4**	**21.3**	**39.1**	**14.8**	88.9	63.1	**39.1**	**14.8**	69.4
	TD4yr	70.0	80.0	83.8	90	100	85	83.8	90	96.3
	TD5yr	90.9	87.5	85.2	81.8	100	88.6	87.5	87.5	96.6
	PPD3yr	**0**	**0**	**1.1**	**0**	59.4	**25**	**17.2**	**4.2**	**39.1**
	PPD4yr	**0**	**3.1**	**14.8**	**10.3**	79.5	**26**	**31.9**	**17.9**	**47.1**
	PPD5yr	62.5	**44.8**	**18.2**	**20.8**	95.9	**32.4**	51.1	**41.5**	62.5

Note. TD = typically developing; PPD = protracted phonological development, yr = years; LProm = left-prominent (word-initial stress); CRProm = centre- and right-prominent (word-medial or word-final stress). No /l/ targets were elicited in CRProm words. Full Match = both segments of the cluster match the target, small deviations in voicing or exact place ignored. Timing Unit (TU) Match: Both matches and substitutions for cluster consonants are considered matches. Only Full Match scores are reported for singletons because singleton deletion was rare. Bold = < 50% match.

In contrast, there were no significant age effects for the comparison target /l/. Singleton /l/ showed mastery across age groups; /l/ clusters showed near-mastery at ages 3 and 4, and mastery at age 5 (Full Match: F (2, 27) = 3.165, p = .058, partial η^2 = .19; Timing Unit Match: F (2, 27) = 1.937, p = .164). Individual /l/ clusters generally matched adult targets except for /gl/ (Table 8). Singleton versus cluster /l/ showed only a non-significant higher match for singleton /l/, Mann-Whitney, p = .125, i.e. a ceiling effect. Comparing segmental targets, /l/ was overall significantly more advanced than the rhotics as predicted: singletons, U = 151.0, z = −5.095, p = .001, r = .7681, a large effect size; clusters, U = 287.0, z = −2.468, p = .014, r = .3186, a small effect size.

In terms of word stress, rhotic clusters showed an increase in accuracy between ages 3/4 and age 5; this difference was significant only for the centre- and right-prominent words: (1) Full Match: H (2) = 10.129, p = .006; (2) Timing Unit Match: H (2) = 9.073, p = .011. (For left-prominent words, p values for the Kruskal-Wallis were .062 for Full Match and .292 for Timing Unit Match.) Overall in terms of stress, rhotic clusters were slightly more accurate in initial stressed syllables (left-prominent word stress) than in unstressed syllables (centre- or right-prominent word stress), a significant difference for Timing Unit Match (U = 591.0, z = 2.220, p = .026, r = .2866) but not, however, for Full Match (p = .216).

Table 8. Chilean and Granada preschoolers: Percent Full Match for individual word-initial rhotic and lateral clusters.

		/r/-clusters							/l/-clusters			
		Labial			Coronal		Dorsal		Labial			Dorsal
Country	Group	/pr/	/br/	/fr/	/tr/	/dr/	/kr/	/gr/	/pl/	/bl/	/fl/	/gl/
Chile	TD3yr	45	75	65	**30**	**30**	50	50	70	85	80	40
	TDy4yr	35	**60**	60	50	**40**	50	**35**	75	85	100	60
	TD5yr	85	100	90	90	90	100	85	100	95	100	80
Granada	TD3yr	**11**	56	**44**	**44**	**11**	**22**	**33**	67	67	68	44
	TDy4yr	90	90	95	80	70	90	65	90	90	90	50
	TD5yr	91	91	91	82	55	55	86	86	93	91	82
	PPD3yr	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**36**	**36**	**19**	**43**
	PPD4yr	**8**	**11**	**18**	**15**	**15**	**7**	**14**	**30**	**32**	**17**	**36**
	PPD5yr	**19**	**25**	**19**	**0**	**25**	**0**	**25**	**25**	**38**	**38**	**14**

Note. Numbers rounded upwards. TD = typically developing, PPD = protracted phonological development. Clusters /pr/ and /dr/ were in initial unstressed syllables (*princesa, primavera, dragón*). The words *tres* and *cruz* had accurate consonants but frequent vowel epenthesis for TD age 5. **Bold = <50% match.**

For specific tap clusters (Table 8), the lowest matches occurred for the coronal clusters at age 3 (30%), and labial /pɾ/ and dorsal /gɾ/ at age 4 (35%). By age 5, the lowest match levels similarly were for /pɾ/ and /gɾ/, although their voicing cognates, /bɾ/ and /kɾ/ were at 100% match. Thus, these data did not fully confirm expectations for labial clusters as earliest.

Mismatch patterns for rhotics: Chilean preschoolers

Figure 2 displays general mismatch pattern proportions for WI tap clusters. At age 3, the most frequent pattern was C2 Deletion (57%) as predicted. C2 Substitution was next in frequency, followed by minority patterns: C1 Substitution and C2 Deletion, C1 Substitution or Deletion, Cluster Deletion, Vowel Epenthesis and C1C2 Substitution. The 4- and 5-year-olds had a similar profile, although the 4-year-olds showed high and relatively equivalent proportions of C2 Substitution and C2 Deletion and the 5-year-olds, only low equal proportions of C2 Substitution and C2 Deletion. The 3- and 4-year-olds showed low frequencies of combination patterns: C1 Substitution plus C2 Deletion in the 3-year-olds, and C1 Deletion plus C2 Substitution in the 4-year-olds, only for /gr/, as predicted regarding C1 Deletion in Spanish acquisition.

The most common substitutions for tap in clusters (Table 9) for 3-year-olds were coronal rhotic [ɹ] and glottal [h], with two instances each of coronals [l] and [j]. For the 4-year-olds, [j] was most frequent, followed by [l], [ð], and then the rhotic [ɹ]. The 5-year-olds again showed glottal [h] and coronals [j] and [ɹ]. Substitutions for the WI trill /r/ were also primarily coronal: voiced stop [d] was most frequent at ages 3 and 4, with low proportions of tap, [l], [dɹ], [ʝ] and [t]. The age 5 group showed only rhotic substitutions, primarily tap (Table 9).

Summary: Chilean preschoolers

In summary, predictions were partially confirmed for the Chilean preschoolers. There was a general age effect for accuracy of rhotics, particularly in initial unstressed syllables. Complexity of word structure (singleton versus cluster) affected development of /l/ minimally, but not rhotics, tap clusters being in advance of the trill. Unexpectedly, labial clusters were not uniformly more advanced, but there was a probable confound with stress, in that /pɾ/ and

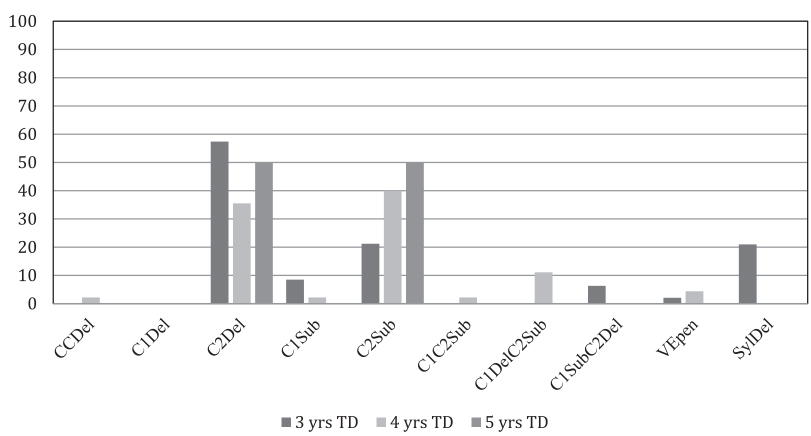

Figure 2. Study 2. Chilean typically developing (TD) preschoolers: Mismatch patterns for rhotic clusters across prominence contexts. C = Consonant; V = Vowel; Syl = syllable; Sub = substitution; Del = Deletion; Epen = Epenthesis. Denominator = total targets.

Table 9. Study 2, Chilean typically developing preschoolers: General mismatch patterns and substitutions for word-initial rhotics.

Target	Age	10+ mismatches	3–9 mismatches	1–2 mismatches
/r/	3 years	**d (24)**	ɾ (5) > dɹ (3)	ʝ̞, t
	4 years	d (10)	dɹ (4) > ɾ, l (3)	t (2) > ʝ̞, ð̞
	5 years		ɾ (3)	ɻ
C/ɾ/	3 years	**C2Del (27)**	C1Sub (ɻ,h: 4 each) > C1SubC2Del (3)	C2Sub (2: j, l) > SylDel, Epen, CC Del
	4 years	**C2Sub** (j: 8; l, ð̞: 4 each; ɻ: 2) > C2Del (16)	C1DelC2Sub (/gɾ/ > [l:2; n, ɻ: 1])	Epen (2) > C1Sub, C1C2 Sub, CC Del
	5 years		C2Sub (h: 2 > j, ɻ: 1) = C2Del (4)	

Note. The numbers in parentheses = number of tokens. TD = typically developing; PPD = protracted phonological development; C = consonant, Del = deletion; Syl = syllable; Epen = vowel epenthesis. C1 Substitutions are not identified. Bold = most frequent.

/{d/ð}ɾ/ were targeted only in centre- or right-prominent words, with the slight disadvantage for that stress context. As expected and following the pattern for the toddlers in Study 1, C2 Deletion was frequent early on, with C2 Substitution increasing in frequency as Timing Unit Match increased. Coronals (except for nasals) commonly replaced the rhotics, less expected stops [t] and [d] for the trill, and including unexpected glottal [h], and fricative/approximant [ð̞] for the tap and [ɹ] for both tap and trill. The [l] was relatively infrequent in comparison with the [j], especially for the older age groups.

Study 3: Granada preschoolers (TD, PPD): Method and results

Method: Granada preschoolers

Participants

Following informed written consent of parents, data were collected from 29 children aged 3 to 5 years with PPD and 30 age-matched TD peers. According to the following tests, all children had normal hearing, oral mechanisms and general language and cognitive skills: *Prueba de lenguaje oral Navarra – Revisada* (PLON-R: Aguinaga, Armentia, Fraile, Olangua, and Uriz, 2004, *Test de Comprensión de Estructuras gramaticales de 2 a 4 años* (Calet, Mendoza, Carballo, Fresneda, and Muñoz, 2010); *Peabody Picture Vocabulary Test - Español* (Dunn, Dunn, and Arribas, 2006); *Test breve de inteligencia de Kaufman* (Kaufman and Kaufman, 2009).

To recruit children with PPD, teachers (with apparent consent) were first asked to suggest children who might show protracted versus typical phonological development in the group. Children may or may not have been receiving speech therapy. Following the above tests, group assignment as TD/PPD was first based on results of the phonology sub-section of the PLON-R and a short conversational sample, then reviewed in relation to the children's Whole Word Match (WWM)[6] scores for the speech sample. One 5-year-old originally classified as PPD was re-classified as TD in accordance with his WWM score. The final TD groups comprised ten 3-year-olds, nine 4-year-olds and eleven 5-year-olds (16 girls and 14 boys with a higher

[6]Whole Word Match indicates the proportion of words that match the adult targets phonetically, slight deviations in voicing, dentalization or vowel quality excepted. Test statistics comparing WWM in each age group supported the final TD/PPD division: U = .3416, 3.97, and 3.633 for ages 3, 4 and 5 respectively, $p < .001$, r = .828 for 3-year-olds; .86 for both 4- and 5-year-olds.

proportion of girls at age 3 [8:2], and a lower proportion of girls at age 5 [3:8]). For children with PPD, there were seven 3-year-olds, fourteen 4-year-olds and eight 5-year-olds (17 boys, 12 girls, with slightly higher numbers of boys in each group).

Procedures

Procedures for the Granada study were the same as those for the Chilean preschool study except for methods for developing reliability of transcription. Prior to data collection in Granada, the research team (Canada, Granada) developed narrow transcription conventions (*cf.* Bernhardt et al., 2015). Two independent transcriptions showed agreement proportions of 96% for the TD group and 94% for the PPD groups. Initial disagreements with respect to clusters concerned tokens with epenthetic vowels or general segment lengthening (fewer than 10% of total mismatches) and all were verified acoustically.

Results: Granada cohort

Match data: Participants

Overall match scores increased by age within each developmental group (TD, PPD) as expected (Tables 7 and 8). For the TD children, the largest differences were between the 3-year-olds and the other groups, with emergent or developing levels at age 3 to near- or full-mastery levels at ages 4 and 5 years. Kruskal-Wallis boxplots showed overlapping, non-significant age scores for /l/ clusters and left-prominent contexts for rhotics. Mann-Whitney tests were used to compare only non-overlapping results: between the 3- and 4-year-old groups for centre- and right-prominent scores, and total scores for the singletons and the tap cluster. (A p value of .007 was set for Bonferroni correction.) An age effect was observed between ages 3 and 4 for all tested variables (large effect size) except for singleton /l/ (p = .113):

(1) C/ɾ/, Timing Unit Match: (a) Centre- and right-prominent words: U = 78.0, z = 3.477, p = .001, r = .8195; (b) All words: U = 71.5, z = 2.759, p = .006, r = .6503;
(2) C/ɾ/, Full Segmental Match: (a) Centre- and right-prominent words: U = 79.5, z = 3.597, p = .001, r = .8478; (b) All words: U = 74.5, z = 3.018, p = .003, r = .7113;
(3) Singleton /r/, Full Match: (a) Centre- and right-prominent words: U = 84.0, z = 3.723, p = .001, r = .7508; (b) All words: U = 82.5, z = 3.110, p = .001, r = .7134;

For the children with PPD, in contrast, the largest match differences were between the 4- and 5-year-old groups, with zero to low match scores at ages 3 and 4 to developing levels for singletons and Timing Unit Match at age 5. There were higher match levels in older groups, but overall levels remained low, especially for tap clusters; Kruskal-Wallis boxplots were non-overlapping only for the singletons; on a Mann-Whitney U comparing 4- and 5-year-olds, only one variable survived Bonferonni correction, Full Match, singleton /r/ (left-prominent): U = 104.0, z = 3.796, p = .01, r = .8283 (a large effect size). Centre/right-prominent contexts for /r/ and total /r/ had p values of .025, i.e. only approaching significance after Bonferroni correction (U = 93, z = 2.816, r = .6145, moderate effect size). Thus, for the children with PPD, age effects were few.

Between developmental groups, the TD group had significantly higher match levels than the PPD groups as expected (moderate to large effect sizes, Bonferroni-corrected p level .008):

(1) Clusters: (a) C/ɾ/: Full Match – $U = 169.50$, $z = -4.253$, $p = .001$, $r = .6344$; Timing Unit Match: $U = 149.0$, $z = -4.359$, $p = .001$, $r = .5675$; (b) Comparison target C/l/: Full Match – $U = 156.0$, $z = -4.377$, $p = .001$, $r = .5698$; Timing Unit Match: $U = 149.0$, $z = -4.359$, $p = .001$, $r = .5675$.
(2) Comparison target singletons: (a) /r/: $U = 138.50$, $z = -4.758$, $p = .001$; $r = .6195$; (b) /l/: $U = 282.0$, $z = -2.190$, $p = .004$, $r = .3789$.

Match data: Word structure

An examination of syllable complexity (singleton versus cluster contexts) for rhotics revealed mixed results as expected. For the TD cohort, match levels were slightly higher for singleton rhotics at age 3 and for tap clusters at age 4 but both targets were near-equivalent at age 5. For the PPD cohort, results were equivalent at age 3, clusters were slightly more accurate at age 4 (both targets showing a very low match), and trill was 30% higher at age 5 (<50% match). Overall, results were not uniform within or between groups, in a sense confirming the uncertainty regarding the prediction. In contrast, and as expected, singleton /l/ was significantly more advanced than /l/ in clusters as expected: for the PPD cohort, $U = 746$, $z = 5{,}145$, $p = .001$, $r = 6755$ (large effect size), and for the TD cohort, $U = 561$, $z = 2.443$, $p = .015$, $r = .318$ (small effect size).

Word stress effects were also examined for rhotic clusters (Table 7). (Comparisons could not be made with /l/, which occurred only in left-prominent words, or with singleton trill because there was only one word with left-prominent stress.) As expected, tap clusters had higher match scores in left-prominent words than in centre- and right-prominent words. However, for the TD group, differences were not significant across ages ($p = .802$, Full Match; .633, Timing Unit Match), or even for the youngest group (3-year-olds: $p = .546$). For the PPD group, Full Match scores were not significant ($p = .183$) but the differences for Timing Unit Match were significant ($U = 251.0$, $z = -2.753$, $p = .006$, $r = .3615$, a small effect size). That is, in the PPD cohrot, clusters in *stressed* syllables were more likely to have two cluster timing units, even if the segments did not match the adult targets.

Match data: Segmental variables

As expected, singleton /r/ was less advanced than singleton /l/ across groups (p value set at .008 for Bonferroni correction): Mann-Whitney $U = 667.500$, $z = -6.141$, $p < .001$, $r = .4475$, moderate effect size), with a stronger effect for the cohort with PPD ($U = 77.0$, $z = -5.306$, $p = .001$, $r = .7115$, large effect size). The tap clusters were also less advanced than /l/ clusters (Full Match), athough differences were not significant across groups ($U = 346.5$, $p = .107$) or even for the PPD group alone after Bonferroni correction ($U = 263$, $z = -1.998$, $p = .046$, $r = .2837$).

For individual clusters (Table 8), no statistical analyses were performed because of the small number of targets per cluster. The TD 3-year-olds showed small differences between targets in descending order as follows: (1) as expected, three labial clusters had highest match levels, two with /l/ and one with tap, i.e. /pl/, /bl/, /bɾ/, at 55–68% match; (2) dorsal clusters, labial cluster

/fɾ/ plus coronal cluster /tɾ/ had intermediate level match scores (22–44%); and (3) /pɾ/ and /dɾ/ had the lowest match scores. However, the latter two targets occurred only in unstressed syllables, with prominence already noted as a factor in accuracy. The TD 4-year-olds showed over 80% match for the labial clusters, /tɾ/ and /kɾ/ (all others showing a 50–70% match level); and the 5-year-old TD group, over 80% match for all but coronal cluster /dɾ/ and dorsal cluster /kɾ/.

For the 3-year-olds with PPD, in contrast, there were no matches for tap clusters. Comparison /l/ clusters showed dorsal /gl/ to be most accurate (43%) (possible word familiarity effect of *globo*, 'balloon'), followed by the bilabial clusters /pl/ and /bl/ (35%). The 4-year-olds with PPD showed emergence of tap clusters, labial /fɾ/, coronal /tɾ/ and /dɾ/ and dorsal /gɾ/ (14–17%) and had patterns similar to those of the 3-year-olds with PPD for /l/ clusters. The 5-year-olds with PPD had slightly higher levels for tap clusters (18–25%) than the 4-year-olds with PPD, except for /tɾ/ and /kɾ/ (0 matches) and showed similar levels for the /l/ clusters as the other two PPD groups, although surprisingly, a lower level for /gl/ (14%). Thus, patterns were not completely consistent across the groups in terms of least/most challenging cluster. Overall, as predicted, earliest acquired clusters generally had some labial obstruents (except where stress was a factor) and the latest were either voiced coronal (TD) or voiceless dorsal stops (PPD).

Mismatch patterns for rhotics

There were several mismatch patterns for the WI rhotic cluster, particularly for the PPD groups. Figures 3 and 4 show the most frequent mismatch patterns; (Table 10 shows specific substitutions and numerical frequency of mismatch patterns).

As predicted, the most common pattern was C2 Deletion, e.g. [ˈkuθ] for /ˈkɾuθ/ *cruz* 'cross'. However, clusters with the voiced dorsal or coronal (often pronounced as approximants), were most likely to show C1 Deletion as predicted, e.g. [ɾande] for /ɣ̞ɾande/ *grande* 'big' or

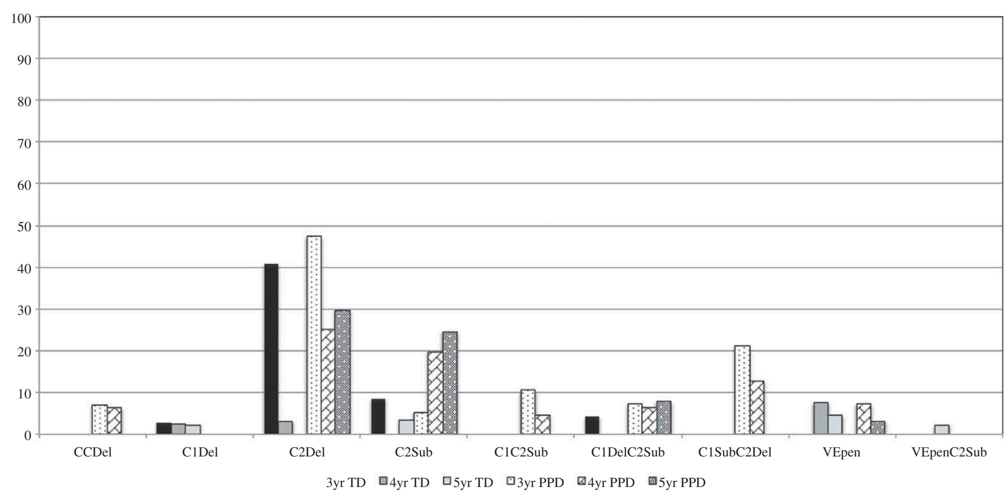

Figure 3. Study 3. Granada preschoolers. Mismatch patterns for rhotic clusters in initial stressed syllables of left-prominent words. TD = typically developing, PPD = protracted phonological development; C = Consonant; V = Vowel; Syl = syllable; Sub = substitution; Del = Deletion; Epen = Epenthesis. Denominator = total targets.

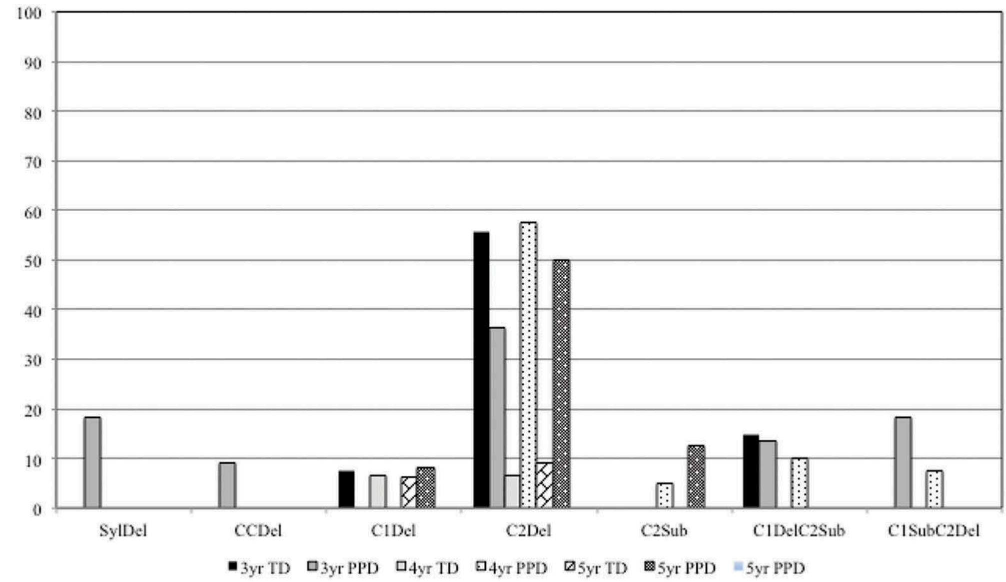

Figure 4. Study 3. Granada preschoolers. Mismatch patterns for rhotic clusters in initial unstressed syllables of centre- and right-prominent words. TD = typically developing, PPD = protracted phonological development; C = Consonant; V = Vowel; Syl = syllable; Sub = substitution; Del = Deletion; Epen = Epenthesis. Denominator = total targets.

Table 10. Study 3. Granada preschoolers: Mismatch patterns for word-initial rhotics.

Target	Age	Group	Frequent mismatches (10+)	3–9 mismatches	1–2 mismatches
/r/	3 years	TD		l (8)> ɾ (5) > d (4) > g, t (3)	CDel, ɹ (2) > z, h
		PPD		l (5) > ɾ (4) > t (3)	d, ð̞ (2) > SylDel; CDel; g, d͡ʒ, ɣ, ʝ, j, n, w, x, ɭ
	4 years	TD		l (4)	g, ʝ, ɺ, d͡ʒ
		PPD	ɾ (20) > d (10)	l (9) > j (5) > ɺ, CDel (4)	gəl, d͡ʑ, ɹ, ɟ, t, n
	5 years	TD		ɾ (4)	r̥, x, k, ɬ
		PPD		l (4)	r̥, ð (2) > dl, f, ɺ, ɾ
C/r/	3 years	TD	**C2Del (45)**	C2Sub (l:7) > C1DelC2Sub (l:5; n:1) > Epen (3)	C1Del, C1SubC2Del (2) > SylDel, C1Sub
		PPD	**C2Del (37)** > C1SubC2Del (17)	CCDel (8)> C1DelC2Sub (l:4, w, j, n) > C1C2Sub (l, w:2; j:1), C2Sub (j:3; l:2) > SylDel (4)	EpenSub (l:2)
	4 years	TD		Epen (6) > C2Del (5) > C1Del, C1DelC2Sub (r, n:1) (2)	C1SubC2Del
		PPD	**C2Del (48)** > C1SubC2Del (20), C2Sub (l:11; j:6; ɺ:3) > C1DelC2Sub (l-6; n-2; j, ð, ɹ:1)	Epen (8)> CCDel (7) > C1C2Sub (j:2; w, l: 1)	C1Sub; C1Del
	5 years	TD		Epen (5) > C2Sub (j:2; ɺ, t: 1) = C1Del, C2Del (4)	EpenC2Sub (t͡ʃ, ɺ) > C1SubC2Del
		PPD	**C2Del (31)** > C2Sub (j: 14 > l:9; ɺ:2; ɹ:1)	C1DelC2Sub (l:2; d, j, r̯: 1) > C1SubC2Del (3)	Epen, C1Del, C1LengtheningC2Del (2 each)

Note. The numbers in parentheses = number of tokens. TD = typically developing; PPD = protracted phonological development (there were 14 4-year-olds with PPD, increasing the absolute number of mismatches in that group); C = consonant, Del = deletion; Syl = syllable; Epen = vowel epenthesis. C1 Substitutions are not identified.

[ɾaˈɣ̞on] for /dɾaˈɣon/. C2 Substitution was next most frequent. The tap showed a range of substitutions (Table 10), [l] being predominant, e g. *fruta* /ˈfruta/ > [ˈfluta] 'fruit'. For the TD groups, [l] represented 60% of the mismatches, followed by [j], lateralized tap (5%, e.g. [dɺaˈɣo] for /dɾaˈɣon/) and other single substitutions ([lj], [r], [t͡ʃ] e.g. [ˈkəʧuθ] for /ˈkɾuθ/).

For the PPD groups, [l] and [j] were closer in frequency (44% versus 39% respectively). The [j] and [l] occurred with all onsets, even the coronals, as in e.g. [dlaˈɣon] for /dɾaˈɣon/ or [ˈtlɛ] for /ˈtɾɛ/ *tres 'three'*. Other infrequent substitutions were: [n] (often in assimilation, e.g. in *dragón*) but also independently, e.g. [ˈnat͡ʃja̰] for /ˈgɾasja/ *gracias* 'thank you'; approximant [ɹ] (e.g. [ˈɹuxa] for /ˈbɾuxa/, and lateralized taps.

Other general minority patterns (left-prominent words only) included complex mismatches, i.e. C1 Deletion *with* C2 Substitution (e.g. [laˈɣon] for /dɾaˈɣon/ *dragón)*, C1C2 Substitution (e.g. [plu] for /ˈkɾuθ/ *cruz*, and Vowel Epenthesis *with* C2 Substitution (e.g. [kuˈlus̪] for /ˈkɾuθ/), these patterns occurring more in the PPD groups. For left-prominent words, only the PPD groups showed C1C2 Deletion (e.g. [ˈas̪ja] for /ˈgɾasja/ 'thank you'), Syllable Deletion (e.g. [ˈs̪es̪a] for /pɾinˈsesa/), or C1 Substitution (e.g. [ˈtɾu] for /ˈkɾu/). Patterns for centre- and right-prominent words were similar, but there was more weak Syllable Deletion in the PPD 3-year-old group and more Vowel Epenthesis in the TD groups.

The comparison target, singleton /r/, showed deletion on occasion (consonant or syllable deletion), but substitution was most frequent (Table 10); at earlier ages/stages, [l] commonly appeared for the trill, e.g. *rojo* /ˈroxo/ > [ˈloxo] 'red', whereas tap was a more frequent substitution in older groups, e.g. *reloj* /reˈl{o/ɔ}{x/h/ø}/ > [ɾeˈlo] 'watch'. Other relatively frequent substitutions across groups included coronal stops [t] and [d], glide [j], voiced affricate [d͡ʒ], dento-alveolar fricative [ð] and lateralized tap [ɺ]. Unique substitutions included glides [w] and approximant [ɹ]. Assimilation sometimes accounted for substitutions e.g. *rojo* /ˈroxo/ > [ˈj̊oxo] 'red'; *regalo* /reˈɣalo/ > [geˈɣ̞alo] 'gift'.

Summary: Granada preschoolers

Predictions were again partially confirmed for the Granada data. As expected, developmental groups (TD/PPD) differed significantly on all match variables. Age effects were less robust, confirmed only for the singleton trill for the group with PPD, and for the TD groups, for rhotics overall by age and in centre- and right-prominent contexts. In terms of word structure variables, stress was statistically significant across age groups only for Timing Unit Match in the PPD group, with some significant findings by age relative to prominence. As expected by structural complexity, lateral clusters were less advanced than lateral singletons but tap clusters were sometimes more advanced than singleton trill. Segmentally, as expected, /l/ was more advanced than the rhotics and certain labial-tap clusters were more advanced early on, but there was a confound with stress similar to the Chilean study with preschoolers.

Relative to mismatches, C2 Deletion was a frequent mismatch early on as expected, with C2 Substitution increasing in frequency by age. Coronals replaced taps and trills as predicted, but [j] was relatively more frequent in the groups with PPD than the TD groups, and tap tended to replace trill in the older age groups more often. Two findings that had not been predicted were: (a) a higher proportion of mismatch combinations in the PPD group (C1 Deletion *plus* C2 Substitution, etc.), cluster and syllable deletion; and (b) more frequent epenthesis in the older TD groups.

Chilean versus Granada TD match comparison

Match data for clusters were compared for the two studies of TD preschoolers, and showed more similarities than differences. The only statistically significant differences (with small effect sizes) were for Full Match for tap clusters (Group X Country: F (2) = 7.579, p = .001, η^2 = .222), and Timing Unit Match for centre- and right-prominent words (Group X Country: F (2) = 9.357, p = .001, η^2 = .261). These effects were most likely due to the relatively low scores of the 4-year-old group in Chile in comparison with the scores of the Chilean 3-year-olds and the (relatively) high scores of the Granada TD 4-year-olds in comparison with the Granada TD 3-year-olds. Further discussion of the import of the similarities and differences are presented below.

Discussion

The current paper is unique in this volume on WI cluster development by reporting on three studies in two dialect areas, and including information concerning toddlers. This final section discusses findings of the three studies in relation to one another.

Predictions

As expected, results of the studies were more similar than different. Where there were differences between the Chilean and Granada TD preschool cohorts, these likely reflected sampling differences in the 3- and 4-year-old groups, where by chance, the Chilean 3-year-olds were slightly more advanced than the Granada 3-year-olds, with the reverse for the 4-year-olds in the two countries (the particular Chilean 4-year-olds being more like the 3-year-olds in Chile). If it were legitimate to put all the children of each age group together from the two countries, the developmental trajectories would likely be more linear.

Overall, development of WI liquids was similar, even though dialect, age and participant groups varied. Regarding segmental accuracy, as expected, the articulatorily more complex rhotics were slower-developing than the simpler dento-alveolar /l/, although the rhotics did approach mastery by age 5 in the TD groups, and even some of the toddlers demonstrated accurate production of tap clusters, similar to what has been found previously (Bosch, 1984; Gómez Fernández, 1997).

In terms of word structure accuracy and effects, Timing Unit Match was expected to be higher overall than Full Segmental Match, because Timing Unit Match simply requires presence of two elements, even if one or both are substitutions. This prediction was upheld, particularly as the children increased in age and cluster reduction decreased. Interestingly, however, an unexpected pattern was more epenthesis in the older and TD samples, reducing potential for 100% Timing Unit Match (see other papers in this issue). Accurate taps and trills require timing and tongue control and vowel epenthesis allows this to happen. Adults in Spanish generally produce a transitional vocalic element between the first consonant and the tap (svarabhakti), and thus as children learn to produce taps and trills, they will likely take the same approach, but with a longer timing trajectory, resulting in full vowel epenthesis at least some of the time.

Because clusters are structurally more complex than singletons, at least lateral clusters were expected to progress more slowly than lateral singletons, and this did occur. However, the predicted order for acquisition of singleton trill versus tap in clusters was not as clear-cut. The toddler singleton data showed earlier acquisition of tap (at least word medially) than trill (in line with previous research, e.g. Bosch, 1984). Similarly, tap clusters sometimes showed higher match levels than the singleton trill at the same age (more in the Chilean data than the Granada data) and taps were more likely to replace trills than the reverse. However, sometimes tap clusters and singleton trills showed equivalent match levels and sometimes trills were more accurate than tap clusters, especially for the 5-year-olds with PPD in Granada. Perhaps for the 5-year-olds with PPD, word structure complexity was more of a challenge than individual segment mastery. Further research with larger groups of older children with PPD would be necessary to replicate this finding (see Klassen, 2017, concerning children with PPD in the Granada cohort, where word structure was a strong factor in predicting phonological outcomes longitudinally).

Further to word structure, rhotic clusters were expected to show higher accuracy in the highly salient and frequent left-prominent, stressed syllable contexts than in the unstressed centre- and right-prominent contexts. This was generally confirmed, although the low number of tokens of words with the initial unstressed syllables indicates a need for further research in this area. One finding of relevance to stress was the higher Timing Unit Match in the PPD cohort in stressed syllables, i.e. deletion was more common in words with initial unstressed syllables (syllable deletion, cluster deletion and consonant deletion).

Relative to feature sequences, rhotic clusters with labials were predicted to show earlier mastery. This was generally confirmed, although there was lower accuracy in the Granada TD 3-year-olds and Chilean TD 4-year-olds for /pɾ/, where the two targets were in unstressed syllables. Like the Bosch (1984) study, the Chilean and Granada cross-sectional studies showed later development of the coronal clusters, particularly for the PPD cohort. The /dɾ/ was elicited in an unstressed syllable in those two studies (*dragón*), reducing the potential for accuracy because of stress, as may have occurred in other previous studies also. However, *tres* was a target word in the Chilean and Granada studies and *tren* occurred frequently in the toddler study, and those are monosyllables. Thus, the coronal stop-tap sequence may be subject to a negative articulatory repetition constraint early on (two iterations with the tongue tip), something that the labial-liquids (lips-tongue tip) avoid with the two articulators (a Not Twice or Obligatory Contour Principle constraint, Bernhardt and Stemberger, 1998). More research is needed on the acquisition of specific cluster sequences in Spanish, with larger numbers of targets across prominence conditions.

Relative to mismatches, the younger children and the children with PPD in the Granada cohort showed a greater variety of mismatch patterns than older TD children. Early phonological systems have more constraints and fewer options for matches across the word, resulting in more complex mismatch types. As expected, deletion was more common in the younger children and children with PPD, and C2 Deletion was much more common than C1 Deletion, as sonority in clusters would predict. The majority of C1 Deletion occurred in sequences with voiced coronal and dorsal 'stops', where the stop may have actually been perceived or represented as an approximant and thus, more sonorous than the tap or lateral (reversed sonority sequence).

In accordance with previous research, coronal substitutions occurred frequently as substitutions for rhotics, particularly [l] and [j], but also including other rhotics, [d] or other sonorants. Overall, [l] was the most common substitution for the Granada cohort, although the PPD cohort also showed a relatively high frequency of [j] substitutions, similar to the toddlers in the first Chilean study. As expected, substitutions came primarily from the adult inventory, and were faithful in place of articulation (coronal) and usually manner (sonorant) to the target. However, the glottal glide [h] appeared in the Chilean preschool cohort as a substitution in tap clusters. A difference between the Chilean and Granada studies concerned substitutions for the WI trill. The Chilean studies reported [d] to be a frequent substitution for WI trill, whereas this was a low frequency substitution in the Granada cohorts compared with the lateral and tap. This difference may have reflected variation between individuals in small samples, or differences in transcribers' perception of stop versus tap (i.e. accepted length for tap versus stop); acoustic analysis of dialect variation would help disambiguate the possible transcription bias in future comparisons. Overall, however, there were few substitutions from outside the adult inventory, and these were rhotic glides or lateral taps, maintaining some aspect of the rhoticity. In at least Chile, there are some rhotic variants in the adult population that are not trill or tap, and so arguably such models may have affected the children's pronunciations.

Future research and clinical implications

In summary, the data in this study uniquely provide criterion reference information for clinical purposes for children from age 1;8 to 5;11 in Chile and Andalusia, Spain. For future research, it would be beneficial to have a larger number of children for each age group to minimize sampling bias, plus additional words for the sample balanced by word stress and feature sequence, thereby allowing more detailed analyses of the effects of those variables on acquisition.

Declaration of interest

The authors have no conflicts of interest in these studies.

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Appendix 1. Study 1. Chilean toddlers: Specific examples of cluster mismatch patterns.

C1 Type	Position	C/l/target	Child Production	Age	Participant	C/ɾ/target	Child Production	Age	Participant
Bilabial (/p, b/)	WI	/'pla.to/ *plate*	['pa.blo]	1;10.7	P2.2	/'{b/β}ɾa.bo/ *applause*	['ba.bo]	1;6.25	P1.2
		/'pla.ta.no/ *banana*	['pa.ta.no]	2;4.28	P4.2	/'pre.mjo/ *prize*	['pe.mjo]	1;10.28	P2.2
	WM	/'so.pla/ *blows*	['o.pa]	1;8.27	P1.3	/'se.{b/β}ɾa/ *zebra*	['se.βa]	2;3.11	P2.1
Labiodental /f/	WI	/'flor/ *flower*	['po]	2;3.13	P3.2	/'fru.ta/ *fruit*	/'fu.ta/	2;3.29	P2.1
		/'flau.ta/ *flute*	['pa.ta]	2.4.17	P3.1	/'fri.o/ *cold*	['fi.o]	2;6.17	P4.2
Coronal (/t/)	WI					/'tren/ *train*	['teː]	1;6.26	P1.2
	WM					/'o.tro/ *other*	['o.to]	1;7.6	P1.3
						/'kwa.tro/ *four*	['kwa.to]	2;4.28	P4.2
Coronal (/t/)	WM					/es.'**tre**.ja/ *star*	['te.ja]	2;6.22	P4.1
Dorsal (k, g)	WI	/'{g/ɣ}lo{b/β}o/ *balloon*	['go.ba]	1;8.6	P1.1	/'{/g/ɣ}ɾan.de/ *big*	['ge.de]	2.4.28	P4.2
			['go.lo]	1;9.11	P2.2				
	WM	/'t͡ʃo.klo/ *corn*	['tjo.ɣol]	2;6.17	P4.2	/'ti.{g/ɣ}ɾe/ *tiger*	['te.ge]	2;2.22	P3.2
		/{b/β}i.si.'kle.ta/ *bicycle*	['ke.ta]	2;6.22	P4.1		['ti.ɣe]		

Note. WI = word-initial; WM = word-medial; P = participant.

Appendix 2. Words Analysed for Studies 2 and 3 (Chilean and Granada Preschoolers).

Target	CC Place sequence	CC Manner sequence	syllables	Prominence (stress) pattern	Word	IPA target	English
/r/			2	Left	rojo	ˈro{x/h}o	red
			2	Right	ratón	raˈto(n)	mouse
			2	Right	reloj	reˈl{o/ɔ}{x/h/ø}	watch
			3	Centre	regalo	reˈ{ɣ̞/g}alo	gift
C/ɾ/	Lab-Cor	Stop-ɾ	3	Centre	princesa	pɾinˈ{s/θ}e{s/θ}a	princess
		Stop-ɾ	4	Centre	primavera	pɾimaˈ{β/b}eɾa	spring
		"Stop"-ɾ[a]	2	Left	brazo	ˈ{b/β}ɾaso	arm
		"Stop"-ɾ[a]	2	Left	bruja	ˈ{b/β̞}ɾu{x/h}a	witch
		Fric-ɾ	2	Left	fresa	ˈfɾesa	strawberry
		Fric-ɾ	2	Left	fruta	ˈfɾuta	fruit
	Cor-Cor	Stop-ɾ	1	Left	tres	ˈtɾ{e/ɛ}{s/θ/ø/ʰ}	three
		"Stop"-ɾ	2	Right	dragón	{d/ð̞}ɾaˈ{ɣ̞/g}{o/ɔ̃}(n)	dragon
	Dor-Cor	Stop-ɾ	1	Left	cruz	ˈkɾu{s/θ/ø/ʰ}	cross
		"Stop"-ɾ	2	Left	grande	ˈ{g/ɣ̞}ɾande	big
		"Stop"-ɾ	2	Left	gracias	ˈ{g/ɣ̞}ɾa{s/θ}ia{s/θ/ø/ʰ}	thanks
/l/			1	Left	luz	ˈlu{s/θ/ø/ʰ}	light
			2	Left	lápiz	ˈlapi{s/θ/ø/ʰ}	pencil
			2	Left	leche	ˈle{t͡ʃ/ʃ}e	milk
			3	Left	lámpara	ˈlampaɾa	lamp
	Lab-Cor	Stop-l	2	Left	playa	ˈplaʝa	beach
		Stop-l	2	Left	pluma	ˈpluma	pen
		"Stop"-l	2	Left	blanco[b]	ˈ{b/β}laŋko	white
		"Stop"-l	2	Left	bloque(s)	ˈ{b/β̞}loke(s)	block(s)
		Fricative-l	1	Left	flor[b]	ˈfl{o/ɔ}{ɾ/l/ø}	flower
	Dor-Cor	"Stop"-l	2	Left	globo(s)	ˈ{g/ɣ̞}lo{β/b}o(s)	balloon(s)

Note. {} = acceptable variants: WI variants occur in both Chilean and Granada dialects; elsewhere, variants are primarily from Granada; ø = acceptable deletion in Granada Spanish. Lab = Labial; Cor = Coronal (alveolar); Dor = Dorsal (velar); Fric = fricative; Left = left-prominent, WI stress; Right = Right-prominent, word-final stress; Centre = centre-prominent, word-medial stress.

[a] "Quotations" indicate that the stop may be acceptably pronounced as an approximant-like fricative.

[b] Elicited twice (once with objects, once with pictures).