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ARTICLE

Singleton consonant onset acquisition in monolingual Granada Spanish-speaking preschoolers with typical versus protracted phonological development: Impacts of word structure and feature constraints

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Abstract

While consonant acquisition clearly requires mastery of different articulatory configurations (segments), sub-segmental features and suprasegmental contexts influence both order of acquisition and mismatch (error) patterns (Bérubé, Bernhardt, Stemberger & Ciocca, 2020). Constraints-based nonlinear phonology provides a comprehensive framework for investigating the impact of sub- and suprasegmental impacts on acquisition (Bernhardt & Stemberger, 1998). The current study adopted such a framework in order to investigate these questions for Granada Spanish. Single-word samples of monolingual preschoolers in Granada (29 typically developing; 30 with protracted phonological development) were transcribed by native Spanish speakers in consultation with an international team. Beta regression analyses showed significant effects of age, developmental group, and word structure variables (word length, stress, position of consonants and syllables within the word); salience, markedness and/or frequency across the phonological hierarchy accounted for many patterns. The study further demonstrates the impacts of sub- and suprasegmental constraints of the phonological system on consonant acquisition.

Keywords: phonological development; Granada Spanish; speech sound disorders

Introduction

Phonological acquisition is a multifactoral process, with many factors contributing to the age and order of acquisition of various segments (consonants/vowels). Studies often summarize consonant development in terms of age of acquisition charts (e.g., McLeod & Crowe, 2018), giving the relative order in which different segments reach a criterion for accuracy across children. While such charts are potentially useful, on their own they do not necessarily elucidate influences of other aspects of the phonological system on segmental acquisition, i.e., sub-segmental content such as place, manner, or laryngeal features (e.g., Jakobson, 1941/1968) or suprasegmental context, such as syllable or word position for the segment (e.g., Ingram, 1974), word stress or word complexity (Mason, 2018). However, constraints-based nonlinear phonological frameworks (Bernhardt & Stemberger, 1998) facilitate analyses of sub- and suprasegmental factors, and have demonstrated the influence of such factors on segmental acquisition, in, for example, Arabic (Ayyad, Bernhardt & Stemberger, 2016), Bulgarian (Bernhardt, Ignatova, Amoako, Aspinall, Marinova-Todd, Stemberger & Yokota, 2019), English (Mason, 2018), European Portuguese (Ramalho & Freitas, 2018) and French (e.g., Bérubé et al., 2020).

To extend this line of research for Granada Spanish, the current study thus adopted a constraints-based nonlinear phonological framework to examine singleton consonant acquisition. The study set out to determine how a consonant's location in syllables, feet, or words and its phonological features affected accuracy and mismatches (errors) during development. Data were collected from monolingual three- to five-year-olds in Granada. The study included both typically developing (TD) children and those with protracted phonological development (PPD), in order to have data from earlier and later developmental phases. Granada Spanish is a sub-variant of eastern Andalusian Spanish, a dialect spoken in south-eastern Spain (Almería, Granada, Jaén, parts of Córdoba and Málaga). Due to historical emigration patterns from southern Spain to the Americas, Latin American dialects resemble Andalusian Spanish; thus, the findings may also be relevant beyond Granada. Only singleton onsets were examined, because codas are optional (and highly variable) in Granada Spanish (Pérez, Vivar, Bernhardt, Mendoza, Ávila, Carballo, Fresneda, Muñoz & Vergara, 2018 describe onset cluster development for the same children.) As background for the study's research questions, the following sections describe the theoretical framework, (Granada) Spanish phonology and previous research on consonant acquisition, especially in Andalusian Spanish.

Constraints-based nonlinear phonology

To explore sub-segmental and suprasegmental effects on consonant acquisition, a framework is needed that draws attention to such factors, i.e., constraints-based nonlinear phonology (Bernhardt & Stemberger, 1998, 2000). We use the framework as a guide, rather than testing its various properties. The following description outlines key features of nonlinear phonology and constraints-based perspectives in turn (see Bernhardt & Stemberger, 1998, 2000 for more in-depth coverage).

The (nonlinear) phonological hierarchy comprises higher level (suprasegmental) word structures (phonological word, foot [stress], syllable, onset/nucleus/rime, timing units), an intermediary segmental level, and sub-segmental features, grouped hierarchically into manner, place and laryngeal sub-groupings. Analyses of consonant acquisition within this framework generally describe a child's matches and mismatches with adult targets for each tier (level) of the hierarchy, independently and in relation to other tiers. Every segment takes some amount of time (encoded as a

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"timing unit"); a timing unit match analysis (TUM) is informative about whether a segment is present at all (whether matching the features of the adult target consonant or not).

The constraints-based perspective taken here follows basic tenets of Optimality Theory (Prince & Smolensky, 1993). There are impediments to production/output (negative "markedness" constraints), but also positive determinants of output ("faithfulness" constraints to output the targets for each specific word). Constraints are emergent from cognition (accessing information from memory, including frequency effects; coordinating elements at the same point in time and across time; etc.; Bernhardt & Stemberger, 1998) and from articulatory-motor factors (e.g., Hayes, 1999); the degree of impact of such constraints ("ranking" of the constraints) is also affected by cognitive and phonetic factors. Each element of the phonology is subject to competition between positive and negative constraints. If the drive to produce a target is more powerful (ranked higher; reflecting higher activation levels) than factors inhibiting its output, the element will appear; if not, some other element will appear, reflecting various constraint interactions. Each tier is autonomous and subject to its own constraints; however, resolutions of constraints reflect constraints on other tiers, because of inter-dependencies within the system (Bernhardt, Stemberger & Charest, 2010). For example, if a high-ranked word structure markedness constraint prohibits initial unstressed syllables, segments within those syllables generally do not survive (#1 below; data from current study, children with PPD);

	Word	Adult	Child	English	Age(Child)/Pattern
(1)	*conejo*	|koˈne{x~h}o|	[__ˈleo]	'rabbit'	3;1(PPD305), weak syllable deletion

If, however, an equally high-ranked faithfulness constraint requires output of [k], it may appear but in a new location (e.g., #2, in which it is linked to the onset slot of the following stressed syllable).

(2) [__ˈkexo] 3;1 (PPD301; Suppl. File 1)

The word-medial (WM) |n| onset of the second syllable is sacrificed, as is the link between |k| and word-initial (WI) position (low-ranked faithfulness constraints). If, alternatively, the vowel of the initial unstressed syllable has sufficient activation to survive, but the onset features do not, due to their low activation in initial unstressed syllables, the syllable may be output but with a mismatched onset (#3-5).

(3) [_oʁ̯ˈeːhɔ] 3;5, WI C deletion

(4) [nõˈnexo] 3;3, WM onset reduplication

(5) [toˈnexo] 3;8, WI Velar fronting

In summary, consonant production can reflect constraints on other phonological tiers (levels). Constraints can affect single features, groups of features, and the context (structure or sequences) in which features and segments occur. (Interactions with the lexicon, morphosyntax and discourse contexts are also relevant – see Bernhardt et al., 2010 – but outside the scope of this paper.)

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Spanish phonology

The following overview describes word structure, vowels and consonants that Granada Spanish-learning children need to acquire. Where known, relative frequencies of forms are indicated because frequency can affect acquisition (Edwards, Beckman & Munson, 2015). Input to children may include characteristics of both Castilian (north-central) Spanish ("castellano") and Andalusian, because Castilian is prevalent in the media and to an extent in educational settings (Moreno, 2009; Narbona, Cano Aguilar & Morillo-Velarde Pérez, 2011). The overview thus describes general aspects of both dialects and draws attention to relevant characteristics of Granada Spanish for this study.

Word structure

By word length, Spanish disyllables are twice as frequent as monosyllables and multi-syllabic words (which can extend to ten syllables: Quilis, 1983). Any syllable may be stressed (Quilis, 2009), although in disyllables, trochaic stress (Stressed-unstressed, Su, e.g., *gato* /ˈ{g~ɤ}ato/ 'cat') is four times as frequent as iambic (uS, e.g., *ratón* /raˈton/ 'mouse'). Stress is also most frequently penultimate (on the next-to-last syllable) in words of three or more syllables (e.g., #2 *conejo*), although final and antepenultimate stress also occur, e.g., *pantalón* /pantaˈlõ(n)/ 'pants' (uuS); *pájaro*, /ˈpaxa.ɾo/ ˈbirdˈ (Suu), i.e., with sequences of unstressed syllables.

Spanish syllables have obligatory nuclei (monophthongs, diphthongs). In Granada Spanish, onsets and codas are optional, but codas are relatively infrequent and onsets, relatively frequent. Contiguous consonant sequences can occur in onset (liquid clusters) and in coda-onset sequences (several, but nasal-obstruent being most common). Although this paper does not focus on codas or contiguous consonant sequences, they were in some test words, potentially influencing singleton onsets in other word positions. Final syllables in Spanish words show skewing by vowel context (high frequency of -C/a/ and -C/o/), which may influence WM consonant output (reduced co-articulatory sequences). In Granada Spanish, WM sonorants and codas show more frequent elision or segmental variation than in other dialects (see Consonants); otherwise word structure in Granada Spanish matches that of other dialects.

Vowels

Vowels are another consonantal context that can influence development (e.g., the high frequency of word-final [WF] C/a/ and C/o/ syllables). Spanish has monophthongs /a, e, i, o, u/, plus falling sonority diphthongs /ai, au, ei, eu, oi, ou/ and rising sonority diphthongs /ia, ie, io, iu, ua, ue, ui, uo/ although triphthongs (e.g., /uei/) occur rarely (RAE, 2011). Vowels show some contextual effects relating to consonant patterns, e.g., (1) before nasal codas, vowels may be nasalized, even when the coda is absent (e.g., *jamon* /xaˈmon/ [xa.ˈmõ]); (2) in Granada Spanish, when dentoalveolar fricatives or liquids weaken or are elided, preceding vowels generally open or lax, e.g., *pez* Castilian /peθ/ Granada, [pɛ] ˈfishˈ; Lloret & Jiménez, 2009).

Consonants

By manner of articulation, Spanish has stops, nasals, fricatives, affricates, glides and liquids (dentoalveolar /l/; tap /ɾ/ and trilled /r/, contrasting rhotics word medially).

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Table 1. Consonants and consonant features of Granada Spanish.

	[Labial]	[Coronal, +anterior]	[Coronal, -anterior]	[Dorsal] [-back]	[+back]	(Glottal)
Stops [-continuant]	p b[a]	t d[b]			k g[c]	
Approximants [+sonorant]	β[a]	ð[b]	ʝ̞[d]	ʝ[d]	ɣ̞[c]	
Fricatives [-sonorant] [+continuant]	f	s/θ[e]	(ʃ)[f]		x[g]	(h)[g]
Affricates [-continuant], [+continuant]			ʧ[f] ʤ[d]			
Nasals [+nasal]	m	n[h]	ɲ	ɲ	(ŋ)[h]	
Lateral [+lateral]		l[i]				
Rhotics [+vibrant] (Tap/trill)		ɾ, r[i]				
(Glides [-consonantal])			j[d]	j[d]		

Note. Matching superscripts[a-c] indicate Spanish allophones and [d-i] key Granada variants (less common options are parenthesized). Nasal and liquid variants interchange in codas, liquids also intervocalically.) Coronal anterior consonants are often dentalized (see [c]). If segments are listed twice they have both features.

[d, f]Palatoalveolar symbols are used but pronunciation is typically alveolopalatal for the voiceless target and palatal for the voiced. Glides /j/, /w/ are elements of diphthongs; /j/ also varies with /ʤ/~/ʝ/.

[e] In Granada Spanish, the anterior coronal fricative varies ([s] ~ [θ] ~ [s̪]) across and within speakers and in coda typically deletes or surfaces as [^{h}] or [h].

(Table 1 displays the consonant inventory with phonological features.) Except for /ɲ/ and /ɾ/, which occur only word medially, singleton onsets occur word initially and medially (Martinez et al., 2003), although some WM sonorant onsets may be elided (e.g., /ɾ/; /ð̞/), especially in Granada Spanish. Glides /j/ and /w/ occur as elements of diphthongs. The former /j/-/ʎ/ contrast (orthographic <y>, <ll>) has neutralized (*yeísmo*) to alternations of [{ʤ ~ j ~ ʝ̞}], e.g., *llave* [ˈ{ʤ ~ j~ ʝ̞}aβe] ˈkey;ˈ *calle* [ˈka{j~ ʝ̞}e] ˈstreet.ˈ

Place of articulation extends from labial to dorsal (velar) for stops, nasals and fricatives. Coronal [+anterior] consonants /t/, /d/, /n/, /l/, /s/ are often produced dentally (Dalbor, 1980).

Stops and affricates contrast in voicing. Voiceless stops are generally unaspirated, although may be aspirated in Granada. Voiced [b, d, ɡ] occur only post-pausally (and in sequences following a nasal, and for /d/, also /l/), alternating elsewhere with approximants [β̞, ð̞, ɣ̞] (Eddington, 2011).

Major characteristics of Granada Spanish singletons are listed below with reference to Castilian (Moya & García, 1995, 2009; Narbona et al., 2011; Quilis, 2009). Coda variations are included, because they may affect onsets during development. There may be within- and between-speaker variation.

Castilian	Granada
/s-θ/ distinction	[θ] only (*ceceo*), [s] only (*seseo*), variation in *seseo/ceceo*, or [s]-[θ] distinction
/ʧ/	[ʧ~ʃ]
Coda /s/	[s~h ~^{h}~Ø]
Orthographic <ll>,<y>	[ʤ] (after a pause); [ʝ̞~j] intervocalically
Coda liquids	Interchange of [r], [l]; elision

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WM sonorants, elision after /o/	More likely to elide (after /o/ and /a/)
Coda /n/	[ŋ] or elision (optional vowel nasalization)

Consonant onset acquisition: expectations and previous research

Exploring the potential impacts of sub- and suprasegmental factors on consonant acquisition first necessitates examination of general factors that can affect development: age and developmental status, phonological salience, frequency and complexity and coordination of consonants across different positions in a word. Potential impacts of the various factors and previous research on Spanish onset acquisition are discussed as a prelude to the questions for the current study.

Speaker variables

All theories assume two speaker variables to be relevant for acquisition: age and developmental status (TD/PPD), with the expectation that overall accuracy will improve with age, and that TD children will have overall greater accuracy and fewer mismatch patterns than age peers with PPD (although specific elements may be exceptions to this pattern.)

Salience, complexity and frequency

General factors affecting phonological acquisition include phonological complexity/markedness (Jakobson, 1941/1968), frequency (Edwards et al., 2015; Pye, Ingram & List, 1987) and salience (Zhu, 2008). Expectations for acquisition, however, depend on the level of focus (word structure, segments, features), interactions and relevance of the various factors.

In terms of Spanish word structure, acoustic salience and frequency suggest that WI singleton onsets might be earlier-acquired in stressed syllables of trochees. If positional salience is also relevant, WM onsets of edge syllables might be earlier-acquired than WM onsets of internal syllables, particularly unstressed internal syllables (Italian: Bortolini & Leonard, 2000).

Segmentally, frequency can play a role (Edwards et al., 2015; Pye et al., 1987); however, markedness/articulatory complexity may be more relevant overall than frequency and acoustic salience: sibilants, affricates and rhotics tend to be later-acquired even though often frequent within languages (McLeod & Crowe, 2018). Visual salience (labiality) may promote earlier acquisition of specific consonants within those categories (Bernhardt & Stemberger, 1998). For Spanish, onset consonant frequency (Guirao & García, 1990) suggests that some consonants should be early (/t, s, k, d, n/), others intermediate (/b, m, p, l, ɾ/), and some late (/g, l, x, f, ʧ, r, ɲ/). Complexity/markedness suggests that the liquids and fricatives in those sets would be later-acquired even if frequent, except potentially in Granada Spanish, where there are various output options for liquids and dentoalveolar fricatives.

Segments, however, are combinations of features. In terms of features, high frequency features not only tend to be mastered early, but also tend to be over-used in mismatches (errors), replacing less-frequent not-yet-mastered features (for which property the former are referred to as "default" features). Default features tend to be less complex (and less marked) than nondefault features. Thus, a segment may be marked, and late-acquired, but a feature of that segment, less marked, and earlier-acquired (for example, manner versus place). For Spanish, /t/ is considered to have default manner, place and voicing features (Bernhardt, Stemberger, Adler-Bock, Ávila, Carballo, Chávez-Peón, Fresneda, Mendoza, Muñoz & Raymond, 2009/2016): [-sonorant,-continuant,-nasal], [-voiced], [Coronal,+anterior]. Not only is /t/ (with its set of default features) often learned early in other languages, but it frequently substitutes for /k/ (nondefault dorsal place) and /s/ (nondefault fricative manner). Exceptions may occur in mismatches involving reduplication/assimilation/migration-metathesis (called RAM patterns henceforth). Stoel-Gammon and Stemberger (1994) note that default features tend to be more prone to RAM, e.g., *toca* /ˈtoka/ > [ˈkoka] or [ˈkota] ˈtouchˈ). Defaults lose the competition with nondefaults in (RAM) patterns where a feature is duplicated or moves from one segment to another. Anticipatory RAM patterns are more common than perseverative (Stoel-Gammon & Stemberger, 1994). Thus, accuracy of WI onsets could be reduced compared with WM onsets, especially in disyllables of Granada Spanish, where codas are uncommon; the default-nondefault sequence may have a greater impact on WI consonant acquisition than salience (by stress of edge position).

Summary of expectations for (Granada) Spanish onset acquisition

The preceding discussion leads to both general and position-based expectations for Granada Spanish onset acquisition.

1. Earlier mastery of consonants by TD and older children than younger children and those with PPD.
2. Delays in acquisition of positionally restricted consonants (which are less frequent overall), i.e., /ɲ/, /ɾ/; voiced stops/approximants) *unless* contextual support promotes their output (e.g., of consonants with vowel features between vowels).
3. For Granada Spanish, earlier acquisition of complex consonants than in other dialects because of the wider range of options for outputs (affricates; /s-θ/; /r-l/; WM sonorants; codas).

WI position

1. Relatively early acquisition of onsets in stressed initial syllables of trochees, because of the high structural frequency and high attentional and acoustic salience, especially for frequent /t, s, k, d, n/, and consonants with frequent (default) features [-continuant], [-voiced], [Coronal,+anterior;

2. Later acquisition of onsets in initial unstressed syllables, because of lower structural frequency and acoustic salience, especially for lower-frequency consonants (/g, l, x, f, ʧ, r/), and those with nondefault features ([+continuant], [+lateral], [+vibrant], [+voiced], Labial, Dorsal).

3. Lowering of WI accuracy due to sequence constraints resulting in anticipatory RAM patterns for WI targets, and with nondefault features triggering RAM more than the reverse;

4. Later acquisition of articulatorily complex segments (fricatives, affricates, liquids), independent of their frequency.

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WM position

Expectations for WM position were:

1. Similar to those for WI onsets in terms of consonant frequency and feature defaults, except that the intervocalic context might promote earlier acquisition of consonants with vocalic features ([+sonorant], [+continuant], [+voiced], [Dorsal]) (Bernhardt & Stemberger, 1998).
2. Unclear predictions for:
   a. WM onsets in trochees (Su): their low acoustic salience in unstressed syllables could delay their acquisition, but their occurrence in high-frequency trochees, with high positional/attentional salience (final syllable), high syllable frequencies (C/a/, C/o/) and greater likelihood of being triggers versus targets of RAM could promote earlier acquisition;
   b. Multisyllabic words:
      i. Generally later acquisition because of higher word complexity but for onsets to internal stressed syllables, (u)uSu(u), lack of clear predictions relative to acoustic salience (stress) versus low attentional salience (internal syllable) and the possibility of being RAM targets from consonants later in the word.

Previous research and expectations

Research on singleton consonant acquisition for Granada (and other Eastern Andalusian) Spanish has examined consonant mastery (González, 1989) and mismatch patterns (Carballo, Marrero & Mendoza, 2000). Table 2 summarizes studies, adopting criteria

Table 2. Singleton consonant mastery by age for Spanish-speaking typically developing monolingual children across dialects: Previous research[a]

Mastery level	Age: Three years	Age: Four years	Age: Five to seven years
		Added consonants	Added consonants
90%+ match in two or more studies	p b t k		
	m n ɲ	d g	
	f ʝ		s θ
	l	ʧ x	r
		ɾ	
70-89% match in two or more studies	d g		
	ʧ x	s θ	
	ɾ	r	

Note. Andalusian data are from Carballo et al., (2000) and González (1989); Andalusian speakers are exposed to Castilian Spanish. American dialects are similar to Andalusian. The inventories are cumulative (additions = new phonemes by age).
[a]Granada (Carballo et al., 2000: 416 children, 2;6-6;5, mismatches); Malaga (González, 1989: 198 children, 3;0-6;11); Castilian Spanish (Bosch, 2004: 293 children, 3;0-7;11); Mexican-American (Acevedo, 1993, Jiménez, 1987: 120 children each, three- to five-year-olds); Chile (Vivar & León, 2009: 72 children, three- to five-year-olds).

from previous research about mastery (McLeod & Crowe, 2018) without taking word structure into account, consistent with those studies. The studies reported full segmental match (FSM), i.e., did not distinguish between partial match (presence of a segment; accuracy of some features) versus deletion of the segment.

Because there are similarities across Spanish dialects (Carballo et al., 2000), and very few papers on Andalusian Spanish, data are reported for different variants, highlighting dialectal differences.

Mastery data (Table 2) of previous research generally met expectations in terms of participant variables (relevance of age, developmental status), consonant frequency and default status: (1) voiceless stops were early-acquired; (2) some segments with nondefault features and intermediate frequency showed intermediate mastery (/b/, nasals, /l/); and (3) /s/ and /r/ showed later mastery (age seven), reflecting their nondefault features and articulatory complexity. The relatively early acquisition of /f/, /ʝ/ and /x/ was not predictable by their low frequency or nondefault status (two nondefault features each). Visual salience, however, might have promoted acquisition of /f/ (early-developing in other languages: McLeod & Crowe, 2018). The variation in possible outputs for fricatives /ʝ/ and /x/ in Andalusian dialects (e.g., [j], [h]) might have facilitated earlier mastery in those dialects.

Some studies of mismatches also met expectations. González (1989: Eastern Andalusian, Malaga) and Bosch (2004: Castilian Spanish) observed descending frequency in mismatch types: substitutions > deletion > coalescence/RAM patterns. In Bosch (2004), RAM patterns were frequently triggered by nondefaults [Labial] and [+nasal] (and [Dorsal], age four). For three-year-olds, she reported mismatches for more marked targets with nondefault features: fronting of /s/; substitution of [s] or [f] for /θ/; lateralization of intervocalic [ð̞]; and deletion of /ɾ/ and fricatives. Carballo *et al.* (2000) documented dialectal features in Granada Spanish-learning children, observing more *ceceo* ([θ]) than *seseo* [s] overall, plus substitution of [r] for /l/ and deletion of WM onsets.

Although previous studies were generally consistent with expectations for acquisition regarding participant variables, consonant frequency/feature status and positional restrictions, studies of Andalusian Spanish were few, and all studies lacked focus on interactions of segments and word structure, two considerations which motivated the current study.

The current study postulate

In order to address the research gaps noted above, the current study set out to investigate sub- and suprasegmental influences on consonant acquisition in Granada Spanish, an understudied dialect, employing a constraints-based nonlinear phonological framework. Building on expectations expressed above, and previous research for Spanish and other languages, specific predictions were postulated for consonant accuracy and mismatches in Granada Spanish relative to: (1) participant groups; (2) word structure-consonant interactions; and (3) consonant features. Where data permitted statistical analyses, the predictions are framed as research hypotheses.

Participant variables

Consistent with previous acquisition studies, age and developmental status were expected to be relevant both for accuracy and mismatch measures.

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Research hypothesis 1a

Older and TD children will have significantly higher overall onset consonant match levels (TUM, FSM) than younger children and those with PPD (Table 2; Pérez et al., 2018: onset clusters, same cohort).

Research hypothesis 1b

Older and TD children will show fewer mismatch patterns, especially deletion and RAM patterns, than younger children and those with PPD (Bosch, 2004; Carballo et al., 2000).

Word structure-consonant interactions

Following data from other languages as cited above (e.g., Arabic, Bulgarian, English, European Portuguese, French) word structure factors were predicted to influence consonant onset accuracy in Granada Spanish – in particular, word length frequency (disyllabic trochees) and salience (stress, location of consonants).

Research hypothesis 2

Onsets will show higher match levels (TUM, FSM) in shorter (less complex, more frequent structurally) versus longer (more complex, less frequent structurally) words (Ayyad et al., 2016; Bérubé et al., 2020; Mason, 2018);

Research hypothesis 3

Onsets will be significantly more accurate (TUM, FSM) in (salient) stressed versus unstressed syllables, especially initial and internal unstressed syllables, unless affected by anticipatory RAM patterns (Bérubé et al., 2020; Bosch, 2004; Stoel-Gammon & Stemberger, 1994).

Individual consonants and features: matches and mismatches

Based on feature default status, frequency, visibility and previous research:

(1) Earlier mastery was expected for non-continuants (except for less frequent /ɡ/ and /ɲ/, each with two nondefault features), /l/ (intermediate frequency), and fricatives /f/ (visible salience), /ʝ/ and /x/ (Table 2 studies).
(2) Later mastery was expected for positionally restricted (less frequent) consonant singletons (/ɲ/, approximant/voiced stop allophones; tap), unless supported by feature contexts (e.g., vocalic features intervocalically) or because of dialectally acceptable WM deletion (/ð/, /ɾ/) (Table 2);
(3) In descending order, mismatches were expected to comprise: substitutions > deletions > assimilation/reduplication (Bosch, 2004; González, 1989), i.e., timing units were expected to show higher match levels than segments, especially in older and TD children;
(4) Defaults were expected to replace nondefaults (Bernhardt & Stemberger, 1998) in substitutions except in RAM patterns, where nondefaults were expected to replace defaults (Bosch, 2004; Stoel-Gammon & Stemberger, 1994).

Method

Participants

Thirty TD Granada Spanish-speaking preschoolers and 29 with PPD participated (Bernhardt et al., 2015). The TD groups included 9 three-year-olds (7 girls:2 boys), 10 four-year-olds (6:4) and 11 five-year-olds (3:8); and the children with PPD, 8 three-year-olds (3:5), 13 four-year-olds (5:8) and 8 five-year-olds (3:5). Parents signed a consent form received from the preschool teachers in accordance with the universities' ethics agreements (Certificate # H09-03040 from the University of British Columbia; University of Granada). All children had age-level hearing, oral mechanisms, and language and cognitive test scores: *Prueba de lenguaje oral Navarra–Revisada* (PLON-R; Aguinaga, Armentia, Fraile, Olangua & Uriz, 2004); *Test de comprensión de estructuras gramaticales de 2 a 4 años* (Calet, Mendoza, Carballo, Fresneda & Muñoz, 2010); *Peabody Picture Vocabulary Test–Español* (Dunn, Dunn & Arribas, 2006); *Test breve de inteligencia de Kaufman* (Kaufman & Kaufman, 2009). The PLON-R phonology subsection and a conversation with the child guided initial assignment to TD/PPD groups; whole word match scores confirmed group assignment (Bernhardt et al., 2015), i.e., the proportion of child words that fully match the adult targets, ignoring slight phonetic deviations (e.g., partial devoicing/voicing; slight advancement/retraction of consonants or vowels; slight lowering/raising of vowels).

Procedures

A native Spanish speaker elicited 103 single words per child through picture-naming. (Supplemental File 1 presents the word list and transcriptions for participant PPD301, male, 3;1.) The sample was audio-recorded with a Microtrack II digital recorder and lavalier microphone placed six to eight inches from the child's mouth (44.1 kHz sampling rate, uncompressed).

Using questions and cloze phrases, the experimenter asked the child to name the pictures. If the child did not produce the word spontaneously, the experimenter provided models for delayed or, if necessary, immediate imitation. The proportion of imitation decreased significantly by age (35-41% of words, age three; 14-17% of words, age five, ANOVAs): TD, WI: $F(2) = 24.493$, $p < .001$; WM: $F(2) = 14.065$, $p < .001$). (2): PPD, WI: $F(2) = 13.292$, $p < .001$;WM: $F(2) = 11.556$, $p < .001$. The majority of utterances were spontaneous and all audible productions were pooled for analysis. (The Results section contains additional information on response types.)

The elicitation yielded 94 singleton onsets in 5 monosyllables, 54 disyllables (47 Su; 7 uS), 24 trisyllables (20 uSu; 3 Suu; 1 uuS), and 9 four/five-syllable words (7 uuSu; 1 uSuu; 1 uuSuu). Onsets with two timing units were excluded: clusters, geminates and consonants preceding rising diphthongs, the latter in case the first element of the diphthong (e.g., /f-**u̲**e/) was treated as the second element of a cluster (/f**w̲**-e/:) (see Kehoe, Hilaire-Debove, Demuth & Lleó, 2008).

Native speakers of Granada Spanish living in Granada (a phonetician and a phonetics undergraduate student) narrowly transcribed 12 initial datasets. A Canadian team transcribed the same datasets independently: two professors with extensive experience in phonetic transcription (one fluent in Spanish), and two speech-language pathology students with graduate training in transcription (a native speaker of Mexican Spanish, and a fluent speaker of Spanish who had lived in Spain). The teams used acoustic analysis to help resolve disagreements in consensus-building meetings, then transcribed the remaining data independently. Between-team percent agreement for all data (phones plus diacritics) was 96% (TD), and 94% (PPD); further consensus-building resulted in final transcriptions.

For analysis, if the child imitated the experimenter, the experimenter's pronunciation was considered the target. Otherwise, targets were based on the child's production with reference to Granada variants. For stop/approximant allophones, stops were considered WI targets post-pausally, and approximants, intervocalically. Native speaker transcribers made final decisions on targets.

Phon 2.2 software (Rose & MacWhinney, 2014) provided data for quantitative analysis. Match (accuracy) data (FSM, TUM) were calculated for onsets (WI/WM) by word length and stress. Preliminary analysis suggested that position of the syllable in the word (final/internal) might affect WM consonants (as in Bortolini & Leonard, 2000, for Italian); thus, WM onsets were compared in internal versus final syllables, e.g., in *zapato* /saˈpato/, 'shoe', WM onsets occur in internal (/p/), and final syllables (/t/). Iambic disyllables were few; thus, their WI onsets were grouped with unstressed onsets of multisyllabic words for analyses concerning stress.

Variables with low numbers of tokens (specific consonants, mismatch types) or lack of independence were analysed descriptively. FSM and TUM were not compared statistically, for example, because FSM subsumes TUM. For the accuracy analysis of individual consonants, mastery levels were set in accordance with previous studies (e.g., McLeod & Crowe, 2018): mastery (90+% match across a participant group); near-mastery (75-89%); developing (60-74%), emergent (39-59%), marginal or absent (< 39%).

Fisher's exact *t* tests were used to compare total mismatches by group, and beta regression models, the analysis of overall consonant match relative to participant and word structure variables. Beta regression models (Grün, Kosmidis & Zeileis, 2012) were used because of significant heteroscedasticity in the sample (e.g., for WI consonants, FSM: $\chi^2_{df=5} = 17.634, p = .003442$; for TUM, $\chi^2_{df=5} = 21.571, p = .000631$) and the type of data (proportions from 0 to 1). The transformation (y * (n-1) + 0.5/n) was applied to the proportion values because, in a beta regression, dependent variables must not have extreme values (0 or 1). The models are fit by maximum likelihood, and produce coefficients that can be interpreted in the same way as in a logit model (log odds). The model also includes phi coefficients, representing a precision parameter (also a log value). When there is less dispersion, the phi coefficient will be statistically significant and is therefore incorporated into the model to obtain the best fit.

Results

Results are described for: (1) response type (imitated/spontaneous); (2) overall consonant match (FSM, TUM); and (3) individual consonants (mastery and mismatches).

Response type

Response type (spontaneous/imitated) showed variable results, some children having higher accuracy in imitated words, some in spontaneous words, and others, equivalent scores in both. There were two minor significant differences in consonant match proportions by response type: (1) At a p value of < .05, overall WI match proportions were higher in imitated versus spontaneous words for three- and five-year-olds, but not after Bonferroni correction ($p < .003$); and (2) WI consonants in unstressed syllables were significantly more accurate in imitation in three-year-olds with PPD ($p < .001$); however, consonants in unstressed syllables were still less accurate than consonants in stressed syllables, consistent with results pertaining to Research Hypothesis 3. Because response type did not influence results, imitated and spontaneous data were pooled.

Overall match and mismatch proportions

Tables 3 to 6 present onset consonant match proportions (FSM, TUM) by age, developmental group (TD/PPD) and word structure variables (length, stress, and for WM onsets, location of the onset-containing syllable in the word, i.e., final/internal). Beta regression models were used to test hypotheses (Supplemental File 2) concerning potential impact of participant and word structure variables on consonant match. Overall mismatch patterns are presented in Table 7 by mismatch types, participant groups and word structure factors.

Research hypothesis 1a: overall consonant match: participant group effects

As expected, older and TD children had overall significantly higher FSM and TUM (Table 3) than younger children and those with PPD ($p = < .001$). FSM showed larger discrepancies between groups than TUM and larger effect sizes (Wald Z): (a) Age Five x Age Three (Z_{WI}: 9.133, Z_{WM}: 9.114) and TD x PPD (Z_{WI}: 8.630; Z_{WM}: -11.354). WM TUM was near- or at-ceiling for all children (minor non-significant differences).

Research hypothesis 1b: mismatches -- participant group effects

Consistent with the match analysis, older and TD children had significantly fewer mismatch patterns (especially deletion and RAM patterns) than younger children and those with PPD ($p < .001$, Fisher's exact *t* test). Mismatch proportion ratios (mismatches/targets) comparing all PPD versus all TD data (Table 7) were respectively: (1) WI: 26.9% PPD: 7.7% TD (482/1790: 134/1742); (2) WM: 27.3%: 8.3% (1710/6270; 404/4857). By age, mismatch proportion ratios for three- versus four- and five-year-olds combined were: (3) WI -- PPD3: PPD4/5 -- 48.4%:18.8% (238/492: 244/1298); TD3:TD4/5 -- 17.2%: 3.4% (93/541: 41/1221); and (4) WM, same age comparisons: PPD -- 40%: 20.5% (345/862: 465/2273); and TD: 15.4%: 2.6% (143/930; 59/2263).

Research hypothesis 2: word length effects

As predicted, with increasing word length, FSM and TUM decreased, especially for three-year-olds (Table 4, Supplemental File 2). The model was a better fit for FSM than TUM: effect sizes (pseudo-R^2) were similar word initially and medially: WI: .61 (FSM): .4 (TUM); WM: .71 (FSM): .32 (TUM). TUM showed a small TD x PPD difference ($p = .013$), but not FSM ($p = .286$). FSM had insufficient variance to covary with word length. For TUM, age was not significant overall but there were three significant Age x Word Length interactions: highest *p* values for consonant match comparisons were found for Age Five x Two- and Three- versus One-Syllable words ($p = .003$, .001 respectively), and for Age Five x PPD x Four- versus One-Syllable words ($p = .004$).

WM consonant match did not differ significantly by word length overall, but for TUM, there were two significant interactions with age and group, consistent with expectations: Age Five x PPD x Four- and Two- versus One-Syllable words ($p = .012$, $p < .001$, respectively).

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Table 3. Full segmental and timing unit match mean proportions (standard deviation) by group for word-initial and word-medial singleton onsets

		Typically Developing			Protracted Phonological Development		
Word position	Match type, target #	Three years ($n = 9$)	Four years ($n = 10$)	Five years ($n = 11$)	Three years ($n = 8$)	Four years ($n = 13$)	Five years ($n = 8$)
Word-initial	Full segmental match	.83 (.08)	.96 (.03)	.98 (.03)	**.52 (.15)**	.75 (.14)	.92 (.04)
	Timing unit match	.96 (.03)	1.0 (.01)	.99 (.01)	.87 (.16)	.96 (.05)	.99 (.01)
	Number of targets	517	629	673	490	812	502
Word-medial	Full segmental match	.85 (.08)	.97 (.03)	.98 (.02)	**.60 (.08)**	**.73 (.10)**	.89 (.05)
	Timing unit match	.97 (.03)	.99 (.01)	1.0 (.01)	.93 (.06)	.96 (.04)	1.0 (0)
	Number of targets	947	1091	1172	863	1029	870

Note. Full segmental match: consonants fully match the target; Timing unit match: consonants present but may be substitution. **Bold:** ≤.74.

Table 4. Mean match proportions by group, word length and word position for singleton onsets (standard deviation: # targets)

			Length of word in syllables						
			1 syllable	2 syllables		3 syllables		4 syllables	4(5) syllables
Match type	Age (years)	TD/PPD	Word-initial	Word-initial	Word-medial	Word-initial	Word-medial	Word-initial	Word-medial
Full segmental match	3	TD	.94 (.11:38)	.84 (.10: 271)	.88 (.08: 427)	.80 (.11: 178)	.86 (.10: 303)	**.74 (.22: 54)**	.77 (.14: 217)
		PPD	.94 (.11:36)	**.55 (.13: 242)**	**.71 (.06: 383)**	**.43 (.21: 162)**	**.55 (.10: 278)**	**.35 (.27: 50)**	**.47 (.22: 202)**
	4	TD	1.0 (.01:50)	.94 (.05: 312)	1.0 (.01: 492)	.96 (.03: 208)	.97 (.03: 347)	.98 (.05: 59)	.95 (.04: 252)
		PPD	.89 (.13:63)	**.74 (.11: 406)**	**.74 (.12: 626)**	**.70 (.21: 266)**	**.72 (.12: 466)**	.79 (.25: 77)	.75 (.24: 311)
	5	TD	1.0 (.01:51)	.97 (.05: 333)	.99 (.02: 533)	.97 (.04: 223)	.97 (.03: 374)	.98 (.05: 66)	.97 (.04: 265)
		PPD	.93 (.10:40)	.90 (.06: 249)	.88 (.05: 397)	.93 (.04: 165)	.87 (.07: 280)	.98 (.05: 48)	.93 (.04: 193)
Timing unit match	3	TD	1.0 (0: 38)	.99 (.02: 271)	.97 (.04: 427)	.95 (.05: 178)	.98 (.03: 303)	.83 (.25: 54)	.97 (.03: 217)
		PPD	1.0 (0: 36)	.93 (.11: 242)	.97 (.04: 383)	.79 (.32: 162)	.95 (.05: 278)	**.69 (.43: 50)**	.82 (.21: 202)
	4	TD	1.0 (0: 50)	1.0 (0: 312)	1.0 (.01: 492)	.99 (.02: 208)	.99 (.01: 347)	1.0 (0: 59)	.98 (.02: 252)
		PPD	.98 (.06: 63)	.98 (.04: 406)	.97 (.04: 383)	.93 (.10: 266)	.97 (.04: 466)	.97 (0: 77)	.93 (.09: 311)
	5	TD	1.0 (0: 51)	1.0 (.0: 333)	1.0 (.01: 533)	.99 (.03: 223)	1.0 (0: 374)	1.0 (0: 66)	.99 (.02: 265)
		PPD	1.0 (0: 40)	.99 (.02: 249)	1.0 (0: 397)	.99 (.02: 165)	.88 (.35: 280)	1.0 (0: 48)	1.0 (.01: 193)

Note. TD=typically developing; PPD=protracted phonological development; Full segmental match: consonants fully match the target; Timing unit match: onset consonant present but may be substitution; **Bold:** $\leq$.74.

Research hypothesis 3a: stress effects

Word initially, FSM and TUM were significantly higher overall in stressed syllables as predicted ($p < .001$), especially FSM (Table 5, Supplemental File 2: Pseudo-$R^{2,}$ FSM, .6881; TUM, . 44). There were also significant differences for developmental and age groups ($p \leq .001$) favouring the older and TD children, except for ceiling scores in TUM for five-year-olds (as in the overall participant-based analysis).

Stress context (with or without interaction with participant groups) also did not affect WM consonant match levels ($p = .516$; Wald $Z = .650$). FSM show significant age differences, however (Ages Five, Four x Age Three, $p = .001$,.007 respectively). Analysis of stress led to a new hypothesis about syllable location in the word (a positional salience variable).

Research hypothesis 3b: WM onsets

WM onsets will have higher match levels in final versus internal syllables of words.

Tables 6 and 7 and Supplemental File 2 present overall WM consonant match by location of the onset-containing syllable. TUM, but not FSM, was significantly higher overall in final versus internal syllables ($p = .026$, pseudo R^2, .39, modest effect; FSM, $p =$ .161). Older and TD children had significantly higher FSM and TUM than younger children and those with PPD ($p = .001$).

Because syllable location was most influential for three-year-olds, WM consonant match was compared for three-year-olds in stressed versus unstressed syllables of word-internal versus final syllables (Table 5; Supplemental File 2). Internal syllables showed a developmental group difference (the TD group scored significantly higher: $p = .001$); the stressed/unstressed syllable difference approached significance ($p = .054$).

In summary, word structure factors (word length, stress, consonant and syllable location in word) affected overall consonant match, especially FSM for younger children and those with PPD. We turn now to individual consonants, where features were also taken into account.

Individual consonants

Individual consonant data are examined in terms of mastery and mismatch patterns. Descriptive analyses are provided (Tables 8 to 11) by developmental group, word position, stress (WI) and location of the onset-containing syllable (WM). Feature mismatches are reported in Table 12 by individual and combined manner, place and laryngeal categories, e.g., manner-place (e.g., /s/ > [k]), manner-voicing (e.g., /s/ > [d]), etc.

TD groups

Word initially (Table 8), TD three-year-olds showed mastery of voiceless stops, nasal /n/, fricative /f/, and approximants [ð, ɣ], and near-mastery of all others but [g] and /r/ (emergent). Stress context had a minor effect on individual consonants: five were more advanced in stressed syllables (/t/, [b], /d/, [ɣ], /r/), versus one ([β]) in unstressed syllables; otherwise stress context was irrelevant (eight had equivalent mastery in stressed/ unstressed syllables). By age five years, only one consonant had not reached mastery: /r/ (near-mastery) in unstressed syllables.

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Table 5. Mean match proportions for singleton onsets by group, stress and location of syllable (standard deviation: # targets)

	Participant groups		Word-initial onsets		Word-medial (WM) onsets			
			Stress of onset-containing syllable				Location of onset-containing syl.	
Match type	Age (years)	TD/PPD	Stressed	Unstressed	Stressed	Unstressed	Final syllable	Internal syllable
Full seg-mental match	3	TD	.89 (.08: 278)	.76 (.10: 263)	.81 (.14: 266)	.86 (.06: 681)	.87 (.08: 653)	.79 (.14: 294)
		PPD	**.64 (.14: 251)**	**.40 (.18: 239)**	**.55 (.12: 243)**	**.62 (.09: 620)**	**.68 (.07: 591)**	**.43 (.17: 272)**
	4	TD	.97 (.03: 321)	.94 (.04: 308)	.96 (.04: 320)	.97 (.02: 771)	.97 (.03: 744)	.95 (.03: 347)
		PPD	.82 (.10: 420)	**.67 (.18: 392)**	.75 (.12: 404)	**.73 (.11: 999)**	**.73 (.10: 966)**	**.74 (.15: 437)**
	5	TD	.99 (.02: 345)	.96 (.04: 328)	.97 (.02: 328)	.98 (.02: 844)	.98 (.02: 819)	.97. (.03: 353)
		PPD	.95 (.02: 262)	.90 (.15: 240)	.88 (.09: 244)	.89 (.04: 626)	.87 (.05: 604)	.92 (.03: 266)
Timing unit match	3	TD	.99 (.01: 278)	.93 (.06: 263)	.98 (.03: 266)	.97 (.03:681)	.97 (.03: 653)	.96 (.03: 294)
		PPD	.96 (.05: 251)	.77 (.29: 239)	.94 (.06: 43)	.92 (.07: 620)	.96 (.03: 591)	.84: (.18: 272)
	4	TD	.99 (.01: 321)	.99 (.01: 308)	.99 (.02: 320)	.99 (.01: 771)	.99 (.01: 744)	.98 (.02: 347)
		PPD	.98 (.03: 420)	.94 (.09: 392)	.97 (.04: 404)	.96 (.04: 999)	.97 (.03: 966)	.93 (.10: 437)
	5	TD	.99 (.02: 345)	.99 (.01: 328)	.97 (.02: 328)	1.0 (.01: 844)	.99 (.01: 819)	.99 (.01: 353)
		PPD	.99 (.01: 262)	.99 (.02: 240)	1.0 (0: 244)	1.0 (.0: 626)	1.0 (0: 604)	.99: (.01: 266)

Note. Syl.: syllable; Full segmental match: consonants fully match targets; Timing unit match: onset present but may be substitution. TD: typically developing; PPD: protracted phonological development. **Bold:** ≤.74.

Table 6. Mean match proportions for word-medial consonants by context for three-year-olds (standard deviation: targets)

Match type	TD/PPD	Final stressed	Final unstressed	Internal stressed	Internal unstressed
Full segmental match	TD	.86 (.12: 71)	.87 (.07: 583)	.79 (.016: 172)	.80 (.15: 99)
	PPD	**.74 (.13: 65)**	**.67 (.08: 529)**	**.48 (.14: 178)**	**.33 (.27: 94)**
Timing unit match	TD	.99 (.04: 71)	.97 (.04: 583)	.97 (.03: 172)	.94 (.06: 99)
	PPD	.98 (.04: 65)	.96 (.04: 529)	.93 (.08: 178)	**.69 (.38: 94)**

Note. Full segmental match: consonants fully match targets; Timing unit match: onset present but may be substitution. TD: typically developing: PPD = protracted phonological development. **Bold**: ≤.74.

Word medially (Table 9), syllable location appeared relevant for three-year-olds but less so for the older children; three-year-olds had mastered all but liquids and approximants [ð, ɣ] in final syllables, but only dorsals /k/ and {/x/h/}in internal syllables. Four-year-olds displayed mastery of all but [ɣ] (near-mastery across contexts) and rhotics (near-mastery in final syllables), and five-year-olds, of all but [ɣ] in internal syllables.

Comparing WI and WM onsets, in three-year-olds, WM onsets in final syllables (stressed/unstressed) were more advanced than WI consonants in stressed syllables, both in number of mastered consonants (nine versus seven) and mastery levels (more near-mastery, WM, versus developing/marginal, WI). By age four, positional differences were minimal.

In terms of mismatches, substitutions were more common than deletions or RAM patterns for the TD groups. Word initially (Table 4), as expected, TD three-year-olds had higher proportions of mismatches (over targets) in unstressed versus unstressed syllables: for substitutions, 29%: 8% (e.g., #6); for deletions, 10%: 1%, (e.g., #7), and for RAM patterns, 6%:.03% (e.g., #7, 8).

(6) *ratón* /raˈton/ [laˈton] ‘mouse’ 3;5 [+vibrant] > [+lateral]

(7) *regalo* /reˈɣalo/ [leˈalo] ‘gift’ 3;5 WM [l] reduplication

(8) [geˈɣalo] 3;8 WM [Dorsal] assimilation

After age three, the infrequent WI mismatches occurred primarily in unstressed syllables (Table 4).

Word medially, for TD three-year-olds, only 5% of unstressed syllables deleted and singleton onset deletion was rarer (#7). After age three, the few WM mismatches were mostly in stressed internal syllables (#10-11, Table 4).

(9) *dinosaurio* /dinoˈsauɾjo/ [diβoˈsauɾjo] ‘dinosaur’ 4;5 [Labial] assimilation

(10) *juguete* /xuˈɣete/ [xuˈ{β~(w)}ete]ˈtoyˈ 10/28 children [Labial] assim.

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Table 7. Singleton onset mismatch proportions (over targets) by group, consonant word position, syllable location and stress

			Word structure mismatches		Substitutions	Reduplication, Assimilation or Migration			
C Position	Group (age in years)	Position & stress of syllable (Mismatches/ targets)	Syl deletion	C deletion	All	Syl redup	C redup	Assimilation	C migration
Word-initial	TD 3	Initial stressed (30/278)		1.1	**8.6**			0.0	
		Initial unstressed (63/263)	**5.3**	**5.7**	**28.9**		3.8	1.9	
	TD 4	Initial stressed (8/239)			2.1		0.0	1.8	
		Initial unstressed (15/308)	0.3	0.3	3.9		2.0	0.3	
	TD 5	Initial stressed (6/346)	0.3		0.6				
		Initial unstressed (12/328)	0.3		3.4			0.3	
Word-medial	TD 3	Final stressed (9/71)		1.4	**11.3**		1.4	1.4	
		Final unstressed (73/585)		1.4	**11.3**		1.4	0.7	1.0
		Internal stressed (41/177)	0.6	2.3	**17.0**		4.5	2.8	2.8
		Internal unstressed (20/97)	5.2		**15.5**		3.1	1.0	5.2
	TD 4	Final stressed (3/90)			2.2			1.1	
		Final unstressed (13/653)	0.2	0.2	2.6		0.2	0.9	
		Internal stressed (11/229)	0.4	0.9	3.5		1.3	1.7	
		Internal unstressed (5/119)		1.7	2.5			0.8	
	TD 5	Final stressed (1/94)			1.1			1.1	
		Final unstressed (16/725)	0.1		1.8		0.3	0.3	
		Internal stressed (9/234)			3.4			0.9	
		Internal unstressed (1/119)	0.8						

Table 7. *(Continued)*

C Position	Group (age in years)	Position & stress of syllable (Mismatches/ targets)	Word structure mismatches		Substitutions	Reduplication, Assimilation or Migration			
			Syl deletion	C deletion	All	Syl redup	C redup	Assimilation	C migration
Word-initial	PPD 3	Initial stressed (93/252)	1 token	2.8	**31.4**		5.6	**10.7**	1.2
		Initial unstressed (145/240)	**15.3**	**12.7**	**34.9**		**14.8**	5.3	1.1
	PPD 4	Initial stressed (74/408)		1.7	**16.4**		1.0	**5.9**	0.3
		Initial unstressed (130/393)	2.8	3.1	**27.2**		6.1	**4.6**	1.5
	PPD 5	Initial stressed (16/256)			6.3			1.6	
		Initial unstressed (24/241)			6.9		2.1	0.8	0.4
Word-medial	PPD 3	Final stressed (17/65)		1.5	**24.6**		**7.7**	**7.7**	1.5
		Final unstressed (175/527)	0.2	1.1	**31.7**	0.4	3.2	**5.9**	1.7
		Internal stressed (92/173)	1.2	2.9	**48.6**	0.6	**14.5**	**12.7**	3.5
		Internal unstressed (61/97)	**19.6**	**7.2**	**36.1**		**14.4**	3.1	2.1
	PPD 4	Final stressed (29/113)		1.8	**23.0**		**6.2**	**5.3**	
		Final unstressed (233/853)	0.1	0.5	**25.8**	0.2	2.5	4.7	1.3
		Internal stressed (73/292)	0.3	2.1	**21.9**		**5.8**	**6.2**	0.7
		Internal unstressed (40/145)	**8.3**	2.1	**15.9**	1.4	4.1	4.8	2.1
	PPD 5	Final stressed (13/68)			**19.1**		2.9		1.5
		Final unstressed (67/536)		0.2	**12.3**	0.2	0.9	0.2	
		Internal stressed (18/176)			**10.2**			2.3	
		Internal unstressed (2/90)		1.1	1.1				

Note. TD: typically developing; PPD: protracted phonological development; Syl: syllable; C: consonant; Redup: repetition of a syllable or consonant;Assimilation: linking features from one consonant to another; Migration: relocation of a feature or segment (may involve metathesis). **Bold:** ≥5%.

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Table 8. Word-initial singleton consonant mastery in typically developing children by stress and manner classes

Age (in years)		C in stressed (S) syllable: Su, (Suu-2 targets – /p, l/); no ʧ~ʃ Mastered 100% (90-99%)	C in stressed (S) syllable: Near-mastery 75-89%	C in stressed (S) syllable: Developing 60-74% (39-59%)	C in unstressed (u) syllable: u(u)S(u); no /f/, /l/ Mastered 100% (90-99%)	C in unstressed (u) syllable: Near-mastery 75-89%	C in unstressed (u) syllable: Developing 60-74% (39-59%)	C in unstressed (u) syllable: Marginal/ absent < 39%
3	Stop	p t k	b d	**g**	p (k)	t	**b** **g**	d
	β,ð,ɣ	ð (1/1) ɣ (2/2)	β		β			ɣ (0/2)
	Nasal	n	m		n	m		
	Fricative	f	s/θ x/h			s~θ x~h		
	ʧ~ʃ ʤ~ʝ		ʤ/ʝ			ʧ~ʃ ʤ~ʝ		
	Liquid		l	(r)				r
4	Stop	p b t k	d g		p t k	b d	**g**	
	β,ð,ɣ	(β)		ð (1/2)	β ɣ			
	Nasal	m n			(m) n			
	Fricative	(f) s~θ x~h			(s~θ) x~h			
	ʧ~ʃ ʤ~ʝ	ʤ~ʝ			ʧ~ʃ ʤ~ʝ			
	Liquid	l		**r**		r		
5	Stop	(p b) t d k g			p b t (d) k g			
	β,ð,ɣ	β			β			
	Nasal	m n			(m) n			
	Fricative	(f) s~θ x~h			(s~θ) (x~h)			
	ʧ~ʃ ʤ~ʝ	ʤ~ʝ			ʧ~ʃ ʤ~ʝ			
	Liquid	(l) r				r		

Note. Where /β, ð, ɣ/ approximant allophones are not indicated, the sample had no targets.

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Table 9. Word-medial (WM) consonant mastery in typically developing children by location of onset-containing syllable

		C in final syllable (all Cs occur)				C in internal syllable (ð, ʧ/ʃ, ʝ/ʤ, r not targeted)		
Age (in years)	Manner	Mastered 100% (90-99%)	Near-mastery 75-89%	Developing 60-74% (39-59%)	Marginal <39%	Mastered 100% (90-99%)	Near-mastery 75-89%	Developing 60-74% (39-59%)
3	Stop	(p) (t) k				k	p t	
	β,ð,ɣ	(β)		(ð) ɣ			β	(ɣ)
	Nasal	(m n) ɲ					m ɲ	n
	Fricative	f (s∼θ) (x∼h)				x∼h	f	**s∼θ**
	ʧ∼ʃ ʤ∼ʝ	(ʧ∼ʃ ʝ∼ʤ)						
	Liquid		l ɾ		r-35%		l	ɾ
4	Stop	p t k				(p) (t) (k)		
	β,ð,ɣ	β ð	ɣ			(β)	ɣ	
	Nasal	(m) n ɲ				(m n ɲ)		
	Fricative	f s∼θ x∼h				f s∼θ x∼h		
	ʧ∼ʃ ʤ∼ʝ	(ʧ∼ʃ ʝ∼ʤ)						
	Liquid	(l)	r ɾ			(l) (ɾ)		
5	Stop	p (t) k				p t k		
	β,ð,ɣ	β ð ɣ				β	ɣ	
	Nasal	(m n) ɲ				m n (ɲ)		
	Fricative	f s∼θ x∼h				f s∼θ (x∼h)		
	ʧ∼ʃ ʤ∼ʝ	ʧ∼ʃ ʝ∼ʤ						
	Liquid	(l r ɾ)				(l ɾ)		

Note. If a consonant is not mentioned, the sample had no targets.

(11) *bañera* /{b~β}aˈɲeɾa/ [{b~β}aˈjeɾa] ˈbathtub 4;3 [+nasal] > [-nasal]

Among feature categories (Table 12), manner was affected more than place or voicing, except at age three for WM consonants in internal syllables (where RAM patterns frequently resulted in place mismatches, e.g., #9). The higher proportion of manner substitutions reflects substitutions for rhotics, especially /r/: tap [ɾ], laterals [l, ɭ], stops [t, d], fricative /s/, approximants [ð, ɹ]. When more than one feature mismatched in a segment, manner-place mismatches were more common (5%: #9) than other conjoint mismatches, e.g., manner-voicing (#12):

(12) *mesa* /ˈmesa/ [ˈpesa] ˈtableˈ 3;5

Children with PPD

Word initially, three-year-olds with PPD showed mastery of /p/ across stress contexts, and in either stress context, mastery or near-mastery for two other labial or coronal noncontinuants or approximants (Table 10). Dorsals and /r/ were marginal/absent and other consonants were developing. By age five, all consonants were at-/near-mastery except for /r/ and dorsals /ɡ/ (developing) and [ɣ] (absent).

By stress context, three-year-olds showed higher mastery in stressed syllables except for /p/, [β] and /n/. However, stress was minimally relevant for individual consonants in four-year-olds with PPD: 10 consonants had equivalent mastery by stress, two were more advanced in stressed syllables ([b], /x/) and two in unstressed (/r/, [ɣ]). Five-year-olds, however, showed more stress effects: six consonants were equivalent by stress context, five were more advanced in stressed syllables, and one (/s/) in unstressed.

Word medially (Table 11) for three-year-olds with PPD, consonant mastery differed by location of the onset-containing syllable: no consonants were mastered in internal syllables, and all except {/x∼h/} (equivalent by location) had higher match levels in final syllables (/p, /t/ and /ɲ/ showing mastery). The four-year-olds showed an increase in word mastery internally, and the five-year-olds, equivalent consonant mastery across contexts, with mastery for all but [ð] (near-mastery), /l/ (more advanced in internal syllables), the rhotics and [ɣ] (developing).

Overall, WM consonants were less advanced in internal syllables until age five. Like the TD children, three-year-olds with PPD showed higher match proportions overall for WM consonants in final syllables than for WI consonants in stressed syllables: in final unstressed syllables, eight WM consonants showed mastery (three) or near-mastery (five), whereas in WI stressed syllables, three consonants (/p/, /d/, [ð]) showed mastery but none, near-mastery.

Order of mismatch pattern frequency for the PPD group was: substitutions > RAM patterns > deletions. Mismatches were frequent in unstressed syllables, but also for WM consonants in internal stressed syllables (Table 7).

Similar to the TD cohort, manner features had more mismatches than place or laryngeal features (Table 12): (1) stops for fricatives (e.g., #12); (2) various substitutions for rhotics (e.g., #13-18 for PPD301); and (3) multiple substitutions for /l/ (up to 40% of

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Table 10. Word-initial (WI) singleton mastery in children with protracted phonological development by stress and manner classes.

Age (in years)	Manner	WI C in stressed syllable (/ʧ~ʃ/ not targeted)				WI C in unstressed syllable (/f/, /l/ not targeted)			
		Mastered 1 00% (90-99%)	Near-mastery 75-89%	Developing 60-74% (39-59%)	Marginal/absent < 39%	Mastered 100% (90-99%)	Near-mastery 75-89%	Developing 60-74% (39-59%)	Marginal/ absent < 39%
3	Stops	(p) (d)		(b) **t**	k g	p		(b t)	d-0% k g-0%
	β,ð,ɣ	ð (1/1)		β		β-2/2			ɣ-0/1
	Nasals			(m) **n**			n	(m)	
	Fricatives			(f) **s~θ**	x				s~θ x
	ʧ~ʃ ʤ~ʝ			**ʤ~ʝ**				(ʧ)	ʤ~ʝ
	Liquids			**l**	r-0%				r-0%
4	Stops	(p)	b t d k	(g)		(p)	t d k	b (g)	
	β,ð,ɣ		β	ɣ		ɣ(1/1)	β		
	Nasals	(m) n				(m n)			
	Fricatives		x	**f s~θ**				**s~θ** (x)	
	ʧ~ʃ ʤ~ʝ	ʤ~ʝ				(ʤ~ʝ)	ʧ		
	Liquids		l		r-0%				r-2%
5	Stops	(p) t (d) k	b g			p t k	b d	(g)	
	β,ð,ɣ		β		ɣ-0/1	β			ɣ-0/1
	Nasals	m n				(m)	n		
	Fricatives	f x	s~θ			s~θ x			
	ʧ~ʃ ʤ~ʝ	ʤ~ʝ				ʧ	ʤ~ʝ		
	Liquids	(l)		**r-63%**				(r-50%)	

Note. Where [β ð ɣ] approximant allophones are not indicated, the sample had no targets.

Table 11. Word-medial singleton consonant mastery in children with protracted phonological development by location of onset-containing syllable.

Age in years	Manner	WM C onset to final syllable (all Cs targeted): Mastered 100% (90-99%)	Near-mastery 75-89%	Developing 60-74% (39-59%)	Marginal/absent < 39%	WM C onset to internal syllable (ð̞, ʧ/ʃ, ʝ/ʤ, r not targeted): Mastered 100% (90-99%)	Near-mastery 75-89%	Developing 60-74% (39-59%)	Marginal/absent < 39%
3	Stops	(p t)		**k**			p	**t**	k
	β,ð,ɣ		β	(ð)	ɣ			**β**	ɣ
	Nasals	(ɲ)	m n					(m ɲ)	n
	Fricatives			(f) **s/θ** (x)				(s/θ x)	f
	ʧ/ʃ ʝ/ʤ		ʧ/ʃ ʝ/ʤ						
	Liquids			**l**	r-0% ɾ				l ɾ
4	Stops	(p t)	k			t	p k		
	β,ð,ɣ	(β)		(ð ɣ)				**β** (ɣ)	
	Nasals	(m n ɲ)					m n ɲ		
	Fricatives		f	**s/θ x**			s/θ	**f x**	
	ʧ/ʃ ʝ/ʤ		ʧ/ʃ ʝ/ʤ						
	Liquids			(l ɾ)	r-11%			**l** ɾ	
5	Stops	p b (t) k				(p t) k			
	β,ð,ɣ	β	ð	ɣ		β		(ɣ)	
	Nasals	m (n) ɲ				m (n ɲ)			
	Fricatives	f (s/θ) (x)				f s/θ x			
	ʧ/ʃ ʝ/ʤ	ʧ/ʃ (ʝ/ʤ)							
	Liquids			**l ɾ (r)**		(l)		ɾ	

Note. Where consonants are not indicated, there were no targets.

Table 12. Feature mismatch proportions by group, word position, syllable location and stress.

C Position	TD/PPD, Age yr	Syllable location, stress	Manner	Major Place	Minor Place	[vd]	Manner & Place	Man. & [vd]	Place & [vd]	Man., Place & [vd]
Word-initial	TD 3	Initial stressed	**4.3**	0.7			0.7			1.8
		Initial unstressed	**11.4**	1.5			6.5			2.7
	TD 4	Initial stressed	0.3	0.6			0.9			
		Initial unstressed	2.9				0.4			0.4
	TD 5	Initial stressed	0.6							
		Initial unstressed	1.5				0.6			
Word-medial	TD 3	Final stressed	**5.6**		1.4		2.8		1.4	
		Final unstressed	**7.2**	0.9	0.9	0.2	0.7			
		Internal stressed	**6.2**	**5.1**	0.6		3.4			0.6
		Internal unstressed	2.1	**6.2**			3.1			3.1
	TD 4	Final stressed	1.1	1.1						
		Final unstressed	1.2	0.9			0.5			
		Internal stressed	0.4	2.6			0.4			
		Internal unstressed					0.8			
	TD 5	Final stressed				1.1				
		Final unstressed	1.5	0.3				0.1		
		Internal stressed	1.3	1.3			0.9			
		Internal unstressed								

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Table 12. *(Continued)*

C Position	TD/PPD, Age yr	Syllable location, stress	Manner	Major Place	Minor Place	[vd]	Manner & Place	Man. & [vd]	Place & [vd]	Man., Place & [vd]
Word-initial	PPD 3	Initial stressed	**12.7**	3.6			5.2			2.4
		Initial unstressed	**11.6**	6.4			**9.5**			2.2
	PPD 4	Initial stressed	**5.9**	2.7			3.4			1.2
		Initial unstressed	**14.0**	3.8			5.3			0.5
	PPD 5	Initial stressed	3.5	0.4			0.4			
		Initial unstressed	4.2				0.5			
Word-medial	PPD 3	Final stressed	4.6	4.6	1.5	1.5	**7.7**			
		Final unstressed	4.9	4.9	3.4		**6.3**	0.2	0.6	0.8
		Internal stressed	**6.9**	6.9	2.9	0.6	**14.5**	2.3	1.7	4.0
		Internal unstressed	11.3	11.3	2.1		**11.3**	4.1		2.1
	PPD 4	Final stressed	**16.8**	1.8			4.4			
		Final unstressed	**12.1**	3.3	1.6	0.6	4.5	0.5	0.4	0.6
		Internal stressed	**8.6**	4.8		0.7	**5.1**	0.7		1.0
		Internal unstressed	1.4	4.1	0.7		2.8	1.4	0.7	3.4
	PPD 5	Final stressed	**14.7**				1.5	1.5		
		Final unstressed	**7.5**	0.6	0.2	0.8	1.5			
		Internal stressed	4.0	1.7			4.0			0.6
		Internal unstressed				1.1				

Note. TD=typically developing; PPD=protracted phonological development; yr = years; [vd] = [voiced]; Major place = labial/coronal/dorsal. Minor place = [anterior], [grooved], [labiodental]. Bold ≥5% mismatches over targets.

targets word medially for three- and four-year-olds, and 23.5% for five-year-olds; #12, 19, 20):

(12)	*jaula*	/ ˈxau̯la/	[kawika]	ˈcageˈ	3;3		
(13)	*euro*	/ˈeuɾo/	[eðo]	ˈEuroˈ		PPD301	/ɾ/ > [ð]
(14)	*escalera*	/e({s~ʰ})kaˈleɾa/	[aṉˈtela̧]	ˈstairsˈ			/ɾ/ > [l]
(15)	*jirafa*	/{x~h}iˈɾafa/	[_aˈfafa]	ˈgiraffeˈ			/ɾ/ > [f] (reduplication)
(16)	*perro*	/ˈpero/	[ˈpeɣo]	ˈdogˈ			/r/ > [ɣ]
(17)	*guitarra*	/{g~ɣ}iˈtara/	[__aˈtaja]	ˈguitarˈ			/r/ > [j]
(18)	*rojo*	/ˈroxo/	[ˈxoxo]	ˈredˈ			/r/ > [x] (reduplication)
(19)	*chocolate*	/ʧokoˈlate/	[ʧokoˈɾate]	ˈchocolateˈ	4;9		
(20)	*regalo*	/reˈɣalo/	[ʤeˈjajo]	ˈgiftˈ	3;3		
(21)	*juguete*	/xuˈɣete/	[xuˈβete]	ˈtoyˈ	5;9		

[Dorsal] place also showed frequent substitution and assimilation (#2-4) in all but the five-year-olds with PPD: 43% of opportunities word initially, 44% medially (age three); 21% of opportunities word initially, 28%, word medially (age four). Mismatches for [Dorsal] were infrequent for five-year-olds, except in cases of labial assimilation (usually from a neighbouring vowel, #22, *juguete,* similar to the TD children). The three-year-olds with PPD showed a high proportion of RAM patterns (19.5% of targets word initially, 16.6% word medially), described below.

RAM patterns: three-year-olds with PPD

RAM patterns appeared across word structures and lengths but we focus on disyllabic words (Supplemental File 4), which have a straightforward stress contrast (Su/uS) and fewer segments to appear in mismatches than in multisyllabic words. It is not always possible to determine whether a feature change reflects assimilation or context-free substitution but the designated RAM patterns were possibilities in each case. Reduplication and assimilation occurred 15-20 times more often than metathesis/migration (Table 7) and, except in words with iambic stress where reduplication was more frequent, were equally frequent.

All consonants were targets of RAM: [Labial], [-voiced] and [+sonorant], least often and coronal liquids, especially unstressed /r/, most often, especially in sequences with /l/ or /t/ (e.g., *reloj*, *ratón*). The most frequent triggers of RAM were WM /ɲ/ and /l/ (#22, 23), /t/ and /k/ (Su) (#24, 25) and round vowels (#21).

(22)	*baño*	/ˈbaɲo/	[ˈmaɲo]	ˈbathroomˈ	(4/8 children)
(23)	*reloj*	/ reˈlɔ(ʰ)/	[leˈlɔ(ʰ)]	ˈclock/watchˈ	(4/8)

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(24)	*ratón*	/raˈton/	[ta(n)ˈton]	'mouse'	(3/8)
(25)	*casa*	/ˈkasa/	[ˈtata]	'house'	(3/8)

Discussion

The current study examined sub- and suprasegmental influences on onset consonant acquisition in Granada Spanish within a framework of constraints-based nonlinear phonology. Consonants and their features were examined independently and in interaction with other elements in the phonological system, determining what was possible (faithfulness constraints) and impossible (negative/markedness constraints). A beta regression analysis examined overall FSM and TUM for WI and WM consonants by word structure contexts (length, stress and location of the onset-containing syllable within words). Individual consonants (matches, mismatches) were also described within their structural contexts (word length, and stress and location of the onset-containing syllable within words) and in terms of their major feature categories. Overall, results replicate findings for other languages, e.g., Bulgarian (Bernhardt *et al.*, 2019), European Portuguese (Ramalho & Freitas, 2018) and French (Bérubé *et al.*, 2020). Results are summarized and discussed in terms of the theoretical framework and previous findings, ending with suggested research and clinical implications.

Consonant match: participant and procedural variables

As expected in a developmental study, older children and TD groups showed significantly higher overall consonant accuracy (especially FSM), except for TUM in older children, when scores were at ceiling. (Older children were less likely to delete syllables or consonants, as shown also in Bosch, 2004, for Castilian Spanish.) Response type (spontaneous/imitated) was not significantly related to accuracy. Thus, methodologies for participant selection and elicitation were sufficient for capturing earlier- versus later-developing phenomena in Granada Spanish consonant acquisition, as in other studies with the same cohort (Bernhardt et al., 2015; Pérez et al., 2018).

For analysis, FSM and TUM were useful measures for capturing differences between structural (TUM) versus segmental constraints (FSM) on output. The younger children with PPD had significantly lower TUM than the TD three-year-olds; their word structures were more basic, losing weak initial or medial syllables and consonants in unstressed or internal syllables. Across age groups, the children with PPD had lower FSM, i.e., segmental (feature-based) constraints were notable even when TUM was at ceiling.

Consonant mastery: word structure and feature influences

Word structure

Consonant match (particularly FSM) was higher in shorter words and stressed syllables across participant groups, significantly for WI onsets, but not overall for WM onsets (with some ceiling effects for the oldest children). Word length was relevant, however, for WM onsets in the PPD cohort, who had less-developed phonologies. Location of the onset-containing syllable was a strong predictor of WM accuracy across groups, especially for

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three-year-olds with PPD: WM onsets had significantly higher match levels in unstressed final than internal syllables (independent of stress), and also than WI stressed syllables, due to the prevalence of anticipatory RAM patterns affecting WI consonants.

In terms of facilitating factors for acquisition, the WI data supports previous research that suggests that frequency (Edwards et al., 2015) and salience (Zhu, 2008) affect consonant mastery. WI onsets of stressed syllables in Spanish (especially disyllabic trochees) are more frequent and acoustically salient than onsets in initial unstressed syllables, especially those in longer words, thus accounting for earlier mastery in those structural contexts.

WM onsets, however, were affected more by attentional salience (syllable location) than acoustic salience: final (word edge) syllables versus word-internal syllables (whether stressed or unstressed). The higher accuracy of WM consonants in final syllables replicates Bortolini and Leonard (2000) for Italian, another Romance language with similar word lengths, stress patterns and consonants. Studies of short-term memory have long noted that initial and final items have an advantage for memory and learning (Ebbinghaus, 1913) compared with internal items. Additionally, final C/a/ and C/o/ syllables are very frequent in Spanish (and Italian), suggesting a possible syllable frequency effect.

Consonant sequences across the word also played a role. Onsets in non-final syllables (whether WM or WI) precede/anticipate other onsets (and the less frequent codas), and thus are more susceptible to interference from following consonants than onsets of final syllables, anticipatory influences being more common than perseveratory (Stoel-Gammon & Stemberger, 1994). Consonant features can further affect vulnerability of consonants in non-final syllables in feature-structure interactions as we note in the section below.

Overall, with respect to word structure constraints, word structure effects pertained in the overall match analyses but also to individual consonants across the inventory, as would be predicted in a hierarchical structure where word structure dominates segments (top-down effects). Sub-segmental influences also influenced development, as we discuss below.

Consonant features

Independent of word structure influences, there were a number of feature-based expectations, i.e., that: (1) frequent consonants, especially those containing more default (and/or frequent) features, would be earlier-mastered than infrequent ones and/or those with more nondefault features; (2) articulatorily complex segments (liquids, dentoalveolar fricatives), especially those with more nondefaults, would be later-acquired, except if there were options for output in Granada Spanish or visual salience might facilitate their acquisition; and (3) mismatches would also be subject to the default/nondefault status of features, with substitutions of defaults for nondefaults being most prevalent, but RAM patterns showing the opposite pattern (replacement of defaults by nondefaults).

The mastery data for individual consonants matched expectations, showing: (1) early mastery of frequent consonants with more default features, e.g., [Coronal,+anterior] for /t/, /d/, /n/ (possibly /l/), manner ([-continuant] for stops/nasals) and voicing ([-voiced]), and later mastery of articulatorily challenging segments with more nondefaults, i.e., affricates, palatal nasal, trilled /r/; (2) early ascendency of articulatorily less complex (and visibly or acoustically salient) nondefaults such as [Labial] and [+sonorant] (nasals, approximants, /l/) compared with more challenging (marked) combinations such as [+continuant,-sonorant] for fricatives/affricates, difficult aerodynamics (rhotics) and placement further back in the mouth (palatoalveolars and dorsals, a particular challenge for the PPD cohort); and (3) a possible dialectal effect, in that the TD five-year-olds demonstrated relatively early acquisition of dentoalveolar fricatives and /r/ qualitatively compared with data from other studies (Table 2).

Substitutions also were subject to feature default status. Replicating Bosch (2004) and González (1989), substitutions were the most common mismatch type in the Granada sample, i.e., word structure was in place prior to segmental development (i.e., TUM before FSM), an expectation of a hierarchy in which structure dominates segments. Substitutions also agreed with predictions relative to features: in context-free patterns, default features usually replaced nondefaults, i.e., (1) for manner features, [+continuant] > [-continuant] (fricatives, sonorants > stops); [+nasal] > [-nasal] (nasals > oral stops, [l]), [+vibrant] > [-vibrant] (trills > fricatives, stops mismatches by, nasals, [l])); and [+lateral] > [-lateral] (/l/ > stops, fricatives, rhotics, nasals); (2) for place, use of default [Coronal,+anterior] for [Dorsal] or [Labial] or [Coronal, -anterior]; and (3) for laryngeal features, use of default [-voiced] for nondefault [+voiced]. In RAM patterns involving sequences, the opposite often applied, i.e., nondefaults replaced defaults (replicating e.g., Bosch, 2004; Stoel-Gammon & Stemberger, 1994); unestablished WM consonants (whether because of their weakly established features or non-salient internal location) can gain strength to survive if they are repeated. Reduplication or feature assimilation requires another consonant slot, usually the WI slot, especially when the WI target consonant has default features and the WM consonant has weakly established nondefault features. The learned nondefault has priority over the system-given default, which is only inserted if nothing else blocks it.

With respect to frequency of feature categories in substitution and RAM patterns, manner mismatches were most common, reflecting in part the later acquisition of the marked and articulatorily complex /r/. In some cases, more than one feature category was affected (typically manner-place, especially in the PPD cohort). Thus, not just the individual feature, but what it needs to combine with, can be a challenge for younger children, especially those with PPD (see Pérez et al., 2018, for cluster mismatch patterns). Features are independent, but interdependent on other features for production (in segments).

A related finding for the three-year-olds with PPD was the presence of multiple mismatch patterns for the same target between or within children. For example, substitutions for trills included: (1) stop [d] (maintaining place and voicing); (2) tap (maintaining place, voicing and rhoticity); (3) fricative [z] (retaining continuancy and voicing), and (4) [l] (maintaining 'liquid' status), etc. Such variability suggests that all of the features for a segment may be represented but are subject to constraints on combining them; a child may be faithful to one feature on one occasion, and to other features on other occasions. The combinatorial constraint remains the same, but the solution may be different on different tokens.

Implications for future research

The current study underlines the multifactoral nature of phonological acquisition and the importance of evaluating influences of word structure and features on the acquisition of consonants. There were strong differences in accuracy depending on word length and stress for WI consonants, and location of the syllable in words (final versus internal) for

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WM consonants. A segment has its own constraints depending on the frequency/markedness/complexity of its features and required combinations, but it also occurs in different contexts that inhibit or facilitate its output. Constraints-based nonlinear phonology provides a comprehensive integrative framework for analysing phonological acquisition data. Competition between faithfulness and markedness constraints within and between hierarchically organized tiers was evident both in the development of the consonant inventory and in the mismatch patterns.

This study is the first of its kind for Granada Spanish. Further studies are needed, however, with larger cohorts and a wider age range, both for Andalusian Spanish and other dialects/languages, with the current questions and methodologies, but also examining possible influences of perceptual, morphosyntactic, lexical, pragmatic and environmental variables. Studies of consonant frequency in conversational speech to and by children would also provide a stronger basis for determining frequency effects in acquisition.

This study used single word elicitation with a standard list in order to ensure content coverage of Granada Spanish phonology across children. The dispersion in scores and significant TD/PPD and age effects on many variables support use of such a list. Although larger studies are often contraindicated by lack of resources, a greater number of tokens per consonant type would allow more statistical analyses of individual consonants and mismatches plus a description of variability. Conversational speech samples would provide naturalistic information for comparison with standard word list elicitations and on frequency in child speech. Elicitation context (imitated versus spontaneous) did not impact results, but further study of response type may provide additional insights.

Clinical application

This study further elucidates similarities and differences in children with typical versus protracted phonological development. The PPD cohort had statistically lower overall match scores, more mismatches, and a less advanced consonant inventory than the TD cohort. Like the Castilian Spanish-speaking cohort with PPD of Bosch (2004), the Granada Spanish-speaking children with PPD (particularly the three-year-olds) showed a higher proportion of word structure mismatches (syllable and consonant deletion) and RAM patterns. Segmentally, fricative stopping, velar fronting and a variety of mismatches for /l/ also distinguished them from their TD peers. Although Bosch (2004) noted frequent use of [l] for /r/ for Castilian-speaking children with PPD, this was not a distinguishing factor for PPD in the current study. The TD groups also substituted [l] for /r/; coda liquids may interchange in Granada Spanish, with possible over-generalization to onsets during acquisition. Further to dialect, in Granada Spanish, the range of acceptable variants for dentoalveolar fricatives possibly resulted in “earlier” mastery of those segments, a reminder that dialect must be taken into account in clinical assessment. Importantly, the study shows the importance of assessing consonant development within various word structure contexts, in terms of defaults and nondefaults and in potentially RAM-triggering sequences.

Conclusion

Consonant acquisition in Granada Spanish is subject to constraints above and below the segment, i.e., on word structure and features. A constraints-based nonlinear phonological framework demonstrated both independent and interdependent patterns in phonological development within and between different levels of the phonological system. The study is consistent with studies of consonant acquisition for other languages and lays a foundation for future research and speech therapy in (Andalusian) Spanish.

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