THE DEVELOPMENT OF MEDIAL AND FINAL CODAS IN PERSIAN

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1. Introduction

A significant area of focus in research on phonological development consists of empirical and formal similarities and differences between child and adult phonological systems. Since the seminal work of Jakobson (1941), research in this area has uncovered both crucial similarities, for example, concerning markedness relations in phonological representations (e.g. Spencer 1986, Fikkert 1994, Demuth 1995, Rose 2000, Gnanadesikan 2004) and longitudinal sequences of phonological development. However, this research is also complicated by issues concerning the type of evidence that children actually use to analyze the properties of the language(s) they are in the process of learning. In this paper, we address this question from the perspective of prosodic development. As we will see, while a look at the phonotactics of adult languages enables a number of predictions about phonological development, these predictions must also be validated from the perspective of the child learners' developing lexicons and the phonological evidence they offer toward learning.

We begin by summarizing a line of research on theoretical relationships between consonantal distributions across languages and syllabification. Addressing this approach from the perspective of phonological development, we then discuss contradictory evidence attested in longitudinal studies of phonological development across languages. As we will see, predictions about development formulated based on the phonotactics of adult languages are to be too limited. We show that phonological development can be best understood from the contents of the learner's own developing lexicons. This research adds to a growing body of evidence on the central relevance of the phonological lexicon for our understanding of acquisition (e.g., Stoel-Gammon 2011 and dedicated commentaries).

2. Background

Piggott (1999) proposes that word-final consonants can be syllabified in two ways across languages. He further proposes that these syllabification options are determined based on segmental distributions within individual languages. In a nutshell, Piggott proposes that in languages which display restricted phonotactic distributions in word-final position (e.g., final consonants restricted in terms of the places or manners of articulation they can display), word-final syllables are syllabified as true codas. An example of this is Spanish, a language in which final consonants are virtually restricted to the coronal (alveolar) place of articulation (e.g., Harris 1969; Hualde 2013; see also Polo 2018; Rose et al. 2022 in the context of phonological acquisition). In contrast, in languages that display little to no restrictions on the distribution of word-final consonants, these consonants are formally

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syllabified as syllable onsets followed by a phonologically empty nucleus position. An example of such languages is French, which allows for word-final consonants across all manners and places of articulation as well as for different types of consonant clusters (e.g., Schane 1968, Kaye & Lowenstamm 1984, and Walker 2001; see also Santos 2007 and Rose et al. 2022 in the context of acquisition).

Building on Piggott's (1999) original proposal, Rose (2003) compares the first language acquisition of medial vs. final post-vocalic consonants across languages. Rose proposes that, from a developmental standpoint, syllable codas should emerge in phonological representations later than word-final onsets since syllable codas involve a larger degree of structural complexity, namely a branching rhyme, than does a syllable onset, also given the typological fact that syllable onsets are universally unmarked. Rose provides support for this hypothesis by comparing the development of medial and final post-vocalic consonants in the speech of first language learners of French and Spanish. In French, word-final consonants are indeed acquired much earlier than word-medial codas while in Spanish, both positions emerge during the same developmental stage. In sum, Rose (2003) provides general support for Piggott's (1999) typology of word-final syllabification.

However, to be validated on broader grounds, this hypothesis must be tested against additional first-language speech data. Indeed, while French and Spanish do display rather different phonotactic distributions, other languages present yet other systems of phonotactic distributions. It thus remains unclear how phonotactic differences may ultimately influence patterns of phonological development.

In this paper, we introduce data from Persian. As we will see, this language presents a hybrid scenario, if compared to that of French and Spanish described above. In a nutshell, the general phonotactics of Persian very much resemble that of French in that both languages allow for a virtually unrestricted set of consonants in both medial and final post-vocalic positions. This should predict a developmental pattern similar to that of French, as Rose (2003) reported. However, as we describe below, the development of post-vocalic consonants in Persian instead follows patterns that much closer align to that of Spanish. Building on this paradox, we then engage in a reconsideration of Rose's original analysis, this time through a consideration of the content of the children's lexicons at each relevant stage of phonological development. We then revisit Rose's original hypothesis in light of these new observations.

We begin this discussion in the next section, starting with a brief summary of the distribution of consonants in French and Persian.

3. Consonant distributions in French and Persian

Since the sound distributions in word-medial and final positions in French and Persian play a vital role in our discussion, we begin with a summary of the consonants allowed in these two positions within each language. As we will see, French and Persian display similar sound distribution whereby virtually all consonants are allowed in word-medial and final positions. Also, both languages allow consonant clusters in word-final positions regardless of the violation of sonority profile.

Starting with French, as summarized in Table 1, this language allows for virtually all consonants in word-medial and final coda positions. French also allows for word-final consonant clusters, which present in a variety of sonority profiles, including rising sonority clusters contradicting the Sonority Sequencing Principle (SSP) (Clements 1990). Examples of this include *martre* [maʁtʁ] 'marten', *arbre* [aʁbʁ] 'tree', and *muscle* [myskl] 'muscle'; similar distributions are also possible in word-medial positions (e.g., *portrait* [pɔʁtʁɛ] 'portrait', *ferblantier* [fɛʁblɑ̃tje] 'tinsmith', *resplendir* [ʁɛsplɑ̃diʁ] 'to shine') (Rose et al. 2022)

Table 1: French post-vocalic sound distributions

	Word-medial position	**Word-final position**
Allowed:	(virtually) all consonants	All consonants Consonant clusters
Examples:	*acteur* [aktœʁ] 'actor' *album* [albɔm] 'album' *astuce* [astys] 'trick'	*pomme* [pɔm] 'apple' *malte* [kalk] 'door' *cadre* [kadʁ] 'frame'

The phonotactics of Persian are strikingly similar. As we can see in Table 2, Persian also allows for all consonants in word-medial and final post-vocalic positions as well as for word-final consonant clusters. Violations of the SSP are also possible within these final clusters (e.g., *ghofl* [ɢofl] 'lock' or *chatr* [ʧatr] 'umbrella').

Table 2: Persian post-vocalic sound distribution

	Word-medial position	**Word-final position**
Allowed:	All consonants	All consonants Consonant clusters
Examples:	*dokme* [docme] 'button' *noghre* [noɢɾe] 'silver' *dandan* [dandɑn] 'tooth'	*sardar* [sardɑr] 'general' *samt* [samt] 'direction' *ghofl* [ɢofl] 'lock'

In sum, if assessed from the perspective of consonantal distributions, French and Persian are essentially similar in that they allow for virtually all consonants their respective phonological inventories to appear in either medial or final post-vocalic positions. Both languages also allow for different types of word-final consonant clusters. In addition, both languages realize syllable stress on the final phonetic vowel of the word.

Given these distributional and prosodic similarities, and in light of the developmental hypothesis proposed by Rose (2003), we should thus expect these two languages to display similar development patterns. However, as we detail in the next section, this hypothesis is not borne out by the facts.

4. Method

In order to systematically assess the theoretical claims summarized above based on cross-linguistic data, our first step was to ensure that all data and methods can be compared across all studies. Taking advantage of the resources available through the PhonBank database (https://phon.talkbank.org; Rose & MacWhinney 2014), which also includes Rose's (2003) original corpus data, we began by replicating the original findings of this study through a reanalysis of the original data using the software program Phon (https://www.phon.ca; Rose & Hedlund 2021). We then studied Persian development following similar data collection and transcription methods and compiled our observations using the same query functions within Phon as we used for the French data.

As part of our larger study, we studied three child learners for each language described above (French, Spanish and Persian). Aside from individual variation, which mostly relates to issues in segmental development, the data on the children's development of medial vs. final post-vocalic consonants is both remarkably similar among learners of each individual language and remarkably different between each of the three languages. In a nutshell, medial and final post-vocalic consonants were acquired during clearly different stages in French but within unique time periods in both Spanish and Persian. Further, Persian-learning children appeared to acquire these consonants at younger ages than what we observed in Spanish-learning children. The detail of these observations for the three languages is presented in Tarahomi (in preparation). In the interest of space, we focus below on a comparison between French and Persian, building on one case study for each language.

The French data presented below are from Théo, a learner of Québec French whose development was recorded between 1;10.26 and 4;00.00. The Persian data come from a monolingual Persian learning child named Parsa, recorded between 1;05.16 and 2;04.11. These data, which document both children from their earliest stages of speech production, were gathered in the tradition of naturalistic studies in which the children were recorded on a more or less fortnight schedule interacting within their everyday family environments.

All datasets were processed following similar methods, resulting in orthographic and phonetic transcripts of the children's attempted speech productions recorded throughout the observation period. These data were then unified within the Phon software program. For this purpose, after verifying the integrity of each corpus, we verified that each transcription of adult over child forms was properly aligned, on a phone-by-phone basis, to best characterize the children's acquisition of each syllabic position relevant to the current study. After completion of this task, we compiled data using Phon query methods. Then, we made one-on-one comparisons between pairs of aligned consonants across syllable positions (e.g., onsets, medial and final codas), both qualitatively and quantitatively. In the last step, we generated timelines for each child to study in detail the children's emergence of phones in word-medial and final codas. The results for the two current children, Théo and Parsa, are represented in the next section.

5. Results

In this section, we describe the development of medial and final post-vocalic consonants in the speech of Théo and Parsa. We present the data in the form of developmental timelines, for each target post-vocalic consonant. In order to abstract away from issues in segmental development, we only report on the presence vs. absence of consonants produced within the relevant positions, irrespective of whether the consonants were segmentally accurate. When a majority of the attempts present in any given session resulted in consonant production (accurate or not), the consonant was deemed to be 'acquired' within this position and marked with a "✓". Failure to realize the position in a majority of attempts resulted in the session marked as "✗" for the consonant. Finally, "-" marks the absence of attempts at this consonant within the session. Building on these observations, we then marked developmental periods through cell shading. Dark shading represents the 'deletion' stage, where no consonants were systematically produced within the relevant positions. Light shading represents the 'production' stage, where the children were able to produce the relevant consonants in a majority of attempts. Because no stages can be identified prior to the children's attempts at words containing consonants within the relevant position, we only added shading to each line from the children's initial attempts at each of the consonants, but did not add shading in cases these initial attempts are isolated within the dataset.

We begin with Théo's medial post-vocalic consonants. As we can see from the timeline in Figure 1, the child had acquired most of the consonants in this position by approximately 3;07.07, with a few of the consonants (e.g. [s]) mastered slightly earlier within this position.

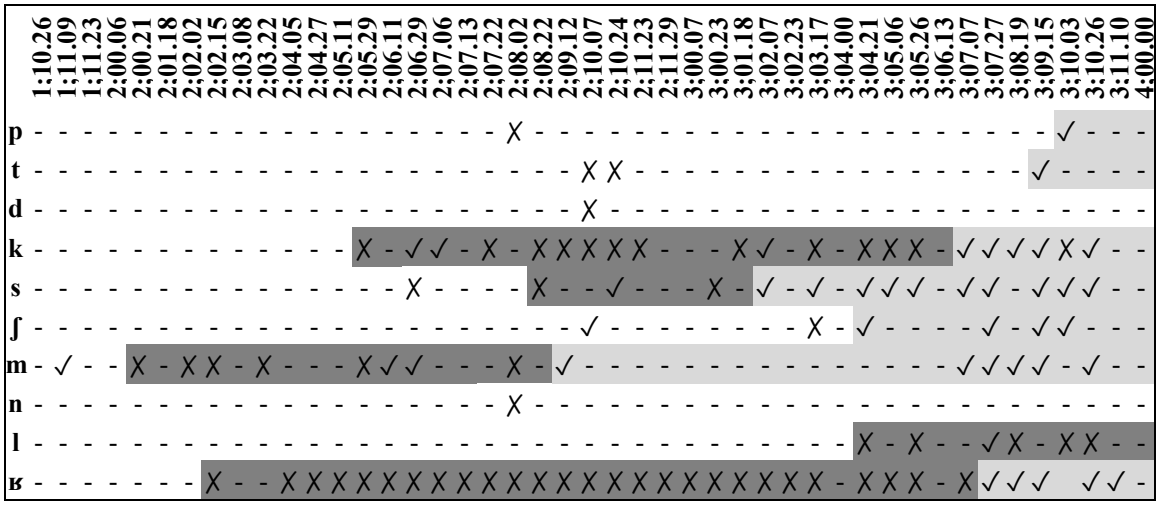

Figure 1. The development of medial post-vocalic consonants in Théo's production

Details about variation between segments aside, the clearest observation emerging from these data is that they starkly differ from Théo's productions in the word-final

position. As we can see in Figure 2, Théo had indeed mastered consonant production in that position more than a year earlier, by 2;05.11.

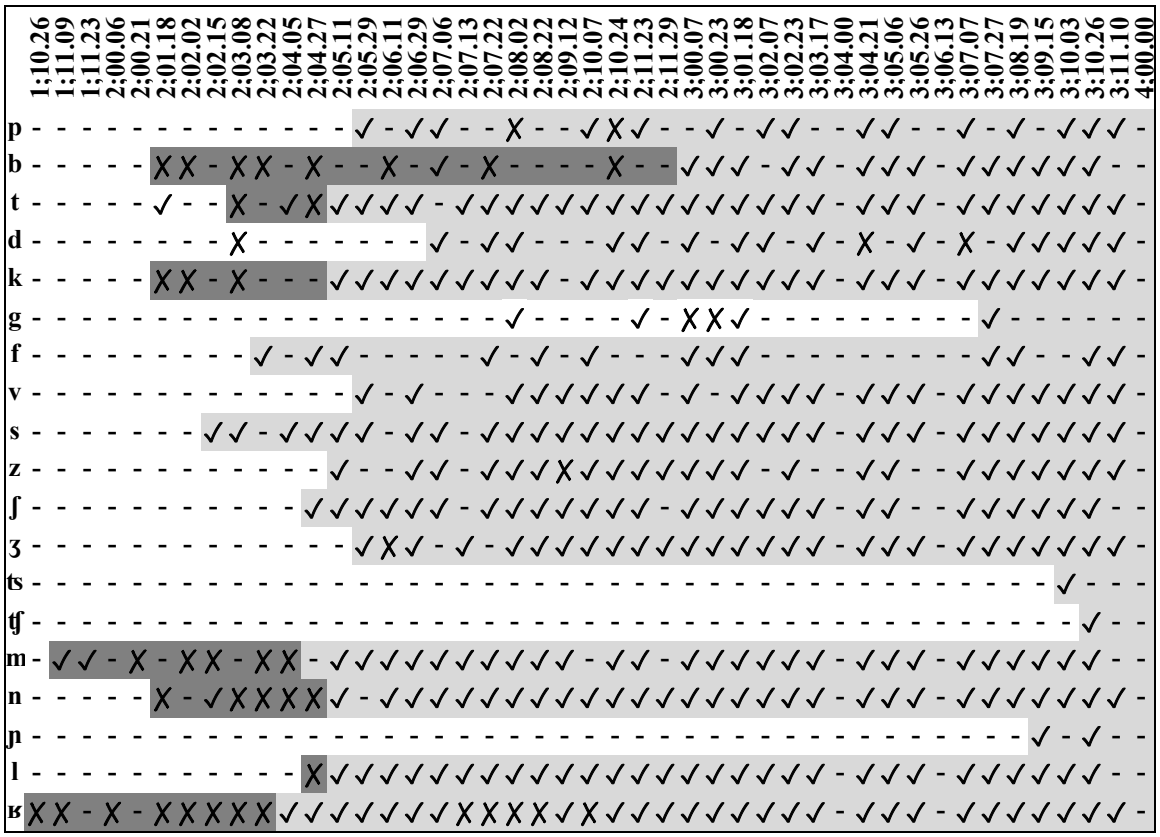

Figure 2. The development of final post-vocalic consonants in Théo's production

The data above thus validate Rose's (2003) original findings for French, whose learners display a clear difference in the rate of acquisition of medial vs. final post-vocalic consonants.

Moving to Persian, we illustrate Parsa's development of medial post-vocalic consonants in Figure 3. As we can see, the child was realizing most of the target consonants in this position already by 1;09.15.

	1;05.16	1;06.20	1;07.10	1;08.15	1;09.15	1;10.22	1;11.20	2;00.07	2;00.21	2;01.12	2;02.01	2;02.26	2;03.19	2;04.11
p	-	-	-	-	-	-	-	X	✓	-	-	-	-	-
b	-	✓	✓	-	✓	-	-	-	✓	✓	✓	✓	-	X
t	-	-	-	-	-	-	✓	-	-	-	-	-	-	X
d	-	-	-	-	-	✓	-	X	X	-	-	✓	✓	X
k	✓	-	-	-	-	X	-	-	✓	✓	✓	✓	-	✓
ɢ	-	-	-	-	-	-	-	-	-	-	-	-	✓	-
f	-	-	-	-	-	-	-	✓	✓	✓	✓	✓	✓	✓
s	-	✓	-	-	-	X	✓	✓	X	✓	✓	✓	✓	✓
z	-	-	-	-	-	-	-	-	-	-	✓	-	-	-
ʃ	-	-	-	-	-	-	✓	-	✓	✓	-	✓	✓	✓
x	✓	-	-	-	-	X	-	-	-	X	-	✓	✓	✓
h	-	X	-	-	X	-	X	X	X	X	X	X	X	-
m	-	-	-	-	-	✓	X	X	X	✓	X	X	X	X
n	-	-	-	-	✓	-	✓	-	✓	✓	✓	✓	✓	✓
ŋ	-	-	✓	-	X	X	-	-	X	-	-	X	✓	✓
l	-	-	X	-	X	-	-	-	-	-	-	✓	✓	-
ɾ	-	-	X	-	X	X	X	X	X	X	X	X	X	X

Figure 3. The development of medial post-vocalic consonants in Parsa's production

These data also reveal variation in Parsa's production of |h|, |m| and liquids, which reflect the child's own difficulties at producing these particular consonants, in addition to a number of lexically-determined exceptional production patterns in a number of high-frequency words (see Tarahomi (in preparation) for additional details; on the exceptionality of high and low frequency words in child language productions, see Menn & Matthei 1992).

Setting aside details about these types of variation, and more central to the argument of the current paper, is a general comparison between Parsa's development of medial post-vocalic consonants and that of his word-final consonants. As we can see in Figure 4, and in contrast to what we saw with Théo's development of French above, Parsa generally acquired both medial and final post-vocalic consonants during the same time period. Again here, this generalization abstracts away from variation caused by issues in segmental development or idiosyncratic patterns of production affecting individual words.

	1;05.16	1;06.20	1;07.10	1;08.15	1;09.15	1;10.22	1;11.20	2;00.07	2;00.21	2;01.12	2;02.01	2;02.26	2;03.19	2;04.11
p	✓	✓	✓	-	✓	-	✓	✓	✓	-	✓	✓	✓	✓
b	✓	✓	✓	-	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
t	-	-	-	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
d	-	-	-	✗	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓
k	-	✗	-	-	✓	✗	-	✗	✓	✗	-	-	✓	✗
g	-	-	-	-	-	-	-	-	-	-	-	-	✓	-
ɢ	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
f	-	-	-	✓	-		✓	✓	✓	✓	✓	✓	✓	✓
s	-	✓	-	-	-	✓	✓	✓	✓	✓	✓	✓	-	-
z	-	-	✓	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
ʃ	✓	✗	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ʒ	-	-	-	-	-	✓	-	-	-	-	-	-	-	-
x	-	✓	-	-	✓	-	-	✓	✓	-	-	✓	-	✓
h	✓	✓	✗	-	✓	✓	-	✓	✓	✓	✓	✓	✓	-
ʧ	-	-	-	-	-	-	-	-	✓	-	-	-	-	-
ʤ	-	-	-	✓	✓	✓	✓	-	-	-	-	-	✓	-
m	-	-	-	-	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓
n	✗	✓	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	✓
ŋ	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
l	-	-	✗	-	✗	✗	✗	✓	✓	✓	✓	✓	✓	✓
ɾ	-	-	✓	✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓

Figure 4. The development of final post-vocalic consonants in Parsa's production

In sum, as illustrated in Théo's data, French learners acquire medial vs. final post-vocalic consonants during two clearly distinct developmental stages. In contrast to this, as we saw through Parsa's data, both positions are acquired relatively early, and during a unique developmental period.

6. Interim discussion

To recapitulate, Piggott (1999) proposed to encode markedness relations within phonotactic distributions in terms of phonological (prosodic) representations. Building on Piggott's proposal, Rose (2003) formulated a developmental approach to this proposal: in languages that display no restrictions on the distribution of final consonants, these consonants are syllabified as onsets of empty-headed syllables, while languages that display restrictions on final consonants syllabify these consonants as true codas (rhymal dependents). As also predicted through structural markedness, onsets of empty-headed syllables should be acquired before (medial or final) codas, given that the latter require the projection of an additional (marked) dependent position within the rhyme.

In section 3 above, we showed that, from both distributional and prosodic perspectives, French and Persian are essentially similar. Based on Rose's (2003) proposal, this predicts that children in both languages should display similar development patterns,

especially in comparison to medial codas, in each language. This is however not the case, as we described above.

In the face of this contradictory result, and also in light of a growing body of literature on phonological development highlighting the central relevance of the child's own lexicon in driving phonological behaviours (e.g., Fikkert & Levelt 2008; Stoel-Gammon 2011; Rose & Penney 2022), we now propose a reconsideration of the developmental data in light of the children's own lexical knowledge at each developmental milestone. As we will see, while Théo's early productive vocabulary provides plenty of evidence for word-final consonants, it is virtually devoid of consonants in medial coda position. In contrast to this, Parsa's vocabulary displays much more similar distributions between the two positions.

7. Consonant distributions as determined through the learners' own lexicons

Keeping with the general view that language-specific speech phonotactics may influence phonological development, we now approach the same hypotheses not based on general descriptions of speech phonotactics in both languages but from the perspective of each child's own vocabulary. In a nutshell, we extracted both the types of post-vocalic consonants we find in the words attempted by each child as well as their frequency of occurrence within the children's data samples. We describe these new findings in the paragraphs that follow.

As we can see in Table 3, at the time Théo mastered the production of final codas (at 2;05.11), his lexicon contained a fair amount of evidence for the presence of word-final consonants in his language. In comparison, there was virtually no evidence for medial codas. An apparent exception to this observation is the consonant |ʁ|, which does appear in noticeable numbers in this table. However, we note that 9 out of the 11 cases of [ʁ] in medial coda come from a single session, recorded at 2;04.27, a mere two weeks before the child mastered consonants in this position.

Table 3. Attested post-vocalic consonants in Théo's productions (by 2;05.11)

Position / Phone	Word-medial	Word-final
b	0	11
p	0	5
d	0	1
k	1	5
f	1	3
s	0	8
ʃ	0	3
m	5	43
n	0	10
l	0	2
ʁ	11	20

Moving to the word-medial position, which Théo mastered only by 3;07.07, we can see in Table 4 a richer inventory of sounds in this position, as well as a relatively higher number of tokens for many of the sounds attested.

Table 4. Attested post-vocalic consonants in Théo's productions (by 3;07.07)

Position / Phone	Word-medial	Word-final
b	3	12
p	0	19
t	5	109
d	1	11
k	24	39
g	0	1
f	1	9
v	1	14
s	5	71
z	0	17
ʃ	1	50
ʒ	0	37
m	13	99
n	1	113
l	1	56
ʁ	57	134

Note as well that, while there are many more types and tokens of medial codas attested within the child's productive lexicon at this second milestone than what we saw in Table 3, this second set presents much more robust evidence for the presence of medial codas within the language than what can be inferred from the first sample. Further, given that these figures come from a single longitudinal sample, we contend that the raw numbers representing the frequency of occurrence are less consequential to our analysis than the attestation of a much larger set of consonants in medial codas, under the view that these consonants must be accommodated within the child's lexical representations. This suggests that, in the absence of a significant sample size, assessments of the evidence available through the child's lexicon based on the different types of consonants attested, as opposed to their numbers in usage, may provide a more representative measure of the evidence available to the learner through his/her own lexicon.

We now compare Théo's data to that of Parsa. We report in Table 5 the numbers of types and tokens of post-vocalic consonants attested in Parsa's lexicon at the time he mastered consonant productions across both of these positions by 1;08.15. As we can see in these data, and in contrast to Théo's first milestone reported above, word-medial codas were represented through noticeable number of consonant types (including obstruent and nasal stops, fricatives and liquids) and also relatively high numbers of tokens, with medial codas even exceeded that of final consonants in the case of [m], [ŋ] and [l].

Table 5. Attested post-vocalic consonants in Parsa's productions (at 1;08.15)

Phone \ Position	Word-medial	Word-final
p	7	12
b	0	43
t	0	1
d	0	5
k	1	1
ɢ	0	10
f	0	3
s	1	2
z	0	1
ʃ	0	3
x	1	4
h	2	52
dʒ	0	10
m	40	1
n	0	86
ŋ	5	0
l	7	3
ɾ	1	8

Finally, similar to our observations from Théo, we argue that while token frequency may at least in part reflect sampling methodology, the inventories of consonant types attested across both positions suggest that Parsa had access, through of his developing lexicon, to noticeably robust evidence for the presence of post-syllabic consonants across both positions from a very early age.

In sum, when described from the perspective of each child's developing lexicon, we obtain a very different picture of the distribution of consonant types and frequency of consonant tokens across medial and final post-vocalic consonants than what we could expect from a general description of the phonotactics of each child's target language. These data, especially that for Théo's first developmental milestone, in turn suggest a tight relationship between lexical knowledge and the development of structural positions to license consonants across prosodic positions.

8. Discussion

Returning to Piggott's (1999) typological and Rose's (2003) developmental proposals, the data descriptions above also have implications for structural approaches to syllabification. In a nutshell, while Piggott and Rose put the burden of analysis on the types of segments that can appear across each post-vocalic position, in particular the types of consonantal place features allowed in each position, our analysis instead suggests that the learning process is instead driven by more general constraints on the distribution of speech sounds

across each position. This, in turn, undermines hypothetical links between segmental contents and syllabification put forth by both Piggott and Rose. Instead, the data from child learners suggest that lexical content is the driving factor for prosodic development, irrespective of particular restrictions on segmental distributions. An ideal test for this particular link should involve languages that present phonotactics that are more similar to Selayarese and Diola Fogny, the two languages that Piggott (1999) used to illustrate his original argument, than those of French or Spanish, which Rose (2003) used as more or less distant proxies to these languages. We leave this question for further research.

The new evidence we introduced from Persian (also representative of two other case studies present in Tarahomi, in preparation) instead suggests that syllable positions and segmental structure are acquired in relative independence of one another, of course, without discounting that properties of each of these domains may at times interact with one another (e.g., prosodic influences on velar fronting; Inkelas & Rose 2007). Further, this new evidence suggests that the development of syllable (and were generally, prosodic) structure in child phonology can be best understood from the phonological properties of the lexical forms present in the child's lexicon, as opposed to that of the target language as a whole. This research may in fact offer connections with studies of infant speech perception that suggest asymmetries between syllable onsets and codas as loci of speech perception (e.g., (Zamuner 2006, 2011, 2013 and references therein).

More generally, this work adds to a growing body of evidence highlighting the centrality as the child's own developing lexicon as a source of explanation for phenomena observed in child phonology. This includes overgeneralizations at the prosodic level (e.g., (Fikkert 1994; Demuth 1996), at the segmental level (e.g., Levelt 1994), or in terms of phonological distributions within word forms (e.g., Fikkert & Levelt 2008, Rose & Penney 2022; see Stoel-Gammon 2011 and related commentaries).

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