# The Acquisition of CCV Branching Onsets in Brazilian Portuguese: Revisiting the Roles of Variation and Phonological Density

Andressa Toni

*State University of Central-West, Paraná, Brazil*

## 1 Introduction

Branching onsets in Brazilian Portuguese are formed by combining an obstruent (/p, b, t, d, k, g, f, v/) with a liquid consonant (/l/ or /ɾ/), followed by a vowel, like in /pɾato/ 'dishplate', /bluza/ 'shirt', /tɾigo/ 'wheat', /flor/ 'flower'. Previous studies determined that children typically begin producing branching onsets before the age of 2, but full acquisition and stabilization of these structures often do not occur until the age of 5 or 6, presenting a developmental process marked by a prolonged period of instability (Teixeira, 1988; Lamprecht, 1993; Miranda & Cristófaro-Silva, 2011). During this period, children often simplify CCV structures by deleting the liquid (reducing CCV to CV, like in /**pɾe**to/ → [ˈ**pe**.tʊ] 'black') or alternating between the lateral (/l/) and flap (/ɾ/) liquids (like in /**pɾe**to/ → [ˈ**ple**.tʊ] 'black', /**blu**za/ → [ˈ**bɾu**.zɐ] 'shirt'), despite being already able to separately articulate CCV syllables and the liquids /l, ɾ/ by the age of 4;0 (Ribas, 2002; Mezzomo, Ribas, 2004; Santos, Toni, 2022).

Throughout the BP acquisitional literature, a longstanding debate discusses whether the late acquisition of this syllable type is due to (i) the complex articulatory properties of CCV; (ii) the phonological properties of the branching syllable; or (iii) the phonetic and phonological properties of the liquid consonants /l, ɾ/ (Mezzomo, Ribas, 2004; Ribas, 2008; Giacchini, Mota, Mezzomo, 2011). The debate also goes around on which of the consonantal sequences are first acquired: some studies defend an initial C/l/V stabilization (Teixeira, 1988; Lamprecht, 1993), others defend an initial C/ɾ/V stabilization (Wertzner, 2003; Queiroga et al., 2011), and others yet defend that there is no predominant order of acquisition between C/ɾ/V and C/l/V (Ribas, 2002; Staudt, Fronza, 2011).

However, comparisons with other Romance languages, such as Spanish, French, and European Portuguese, reveal that CCV structures are acquired significantly earlier in these languages, around ages 3;0-4;0 (Freitas, 1997; Rose, 2000, Nuñez-Cedeño, 2008; Demuth & Mccullough, 2009), suggesting that additional factors besides (i), (ii) and (iii) might be at play in BP. This paper argues that the prolonged acquisition of CCV in BP is influenced by two key factors: (1) variation in adult speech, where CCV structures are sometimes simplified to CV in unstressed positions (like in *Vou pra praia* 'I am going to the beach' > [ˈvow **pɾɐ** ˈpɾa.jɐ] ~ [ˈvow **pɐ** ˈpɾa.jɐ], but *[ˈvow pɾɐ ˈ**pa**.jɐ]) and (2) low phonological density, which reduces the contrastive cues available to children regarding the contrast between CCV-CV (like in /pɾato/ 'dishplate' *versus* /pato/ 'duck') and the contrast between /l/-/ɾ/ in CCV (/blindar/ 'to shield' *versus* /bɾindar/ 'to toast'), but not in CV, since in simple onsets /l, ɾ/ present high phonological density (/ɛla/ 'she' *versus* /ɛɾa/ 'it was'). To support this hypothesis, we present evidence from a corpora study comparing adult speech, child-directed speech and child speech, and from an experimental test combining a picture-naming and a mispronunciation detection task. Data is modelled using the Tolerance Principle (Yang, 2016).

This paper is structured as follows: Section 2 provides an overview of branching onsets in BP and

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presents the results of a corpora study that examines the frequency and distribution of branching onsets in the input. Section 3 describes a mispronunciation detection task designed to test children's sensitivity to the contrast between simple and branching onsets, as well as their ability to detect changes in liquid consonants (/l/ and /ɾ/) both in CV and CCV. Section 4 models the findings using the Tolerance Principle, which explains how children overgeneralize the variational and distributional patterns in the input and eventually overcome these overgeneralizations as their vocabulary grows. Finally, Section 5 concludes highlighting the role of input variation and phonological density in phonological acquisition and suggesting that the prolonged acquisition of CCV in BP is not solely due to motor or structural challenges.

## 2 Corpora study: distributional patterns of CCV in the input

In order to better understand what is happening with branching onsets acquisition in BP, we first looked at the input. We conducted a corpora study analyzing Adult Speech (*ABG corpus*, Benevides & Guide, 2017), Child-Directed Speech (*FDC corpus*, Santos & Toni, 2021) and Child Speech (*FI corpus,* Santos & Toni, 2021),[1] all collected from oral spontaneous interactions. Table 1 presents the type-token frequency of words containing CCV in the corpora, while Table 2 shows the stress and segmental distribution of those words:

| | **AS** | | **CDS** | | **CS** | |
|---|---|---|---|---|---|---|
| | Total words | CCV words | Total words | CCV words | Total words | CCV words |
| *Types* | 36.493 | 6.561 (17,9%) | 12.036 | 1.441 (11,97%) | 10.274 | 622 (0,6%) |
| *Tokens* | 1.938.830 | 139.029 (7,17%) | 396.678 | 19.835 (5%) | 198.917 | 7.531 (3,79%) |

**Table 1:** Type-Token frequency of CCV

| | | ***Types*** | | | | | ***Tokens*** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *%* | *Stressed* | *Pretonic* | *Posttonic* | *Mono* | *Total n* | *Stressed* | *Pretonic* | *Posttonic* | *Mono* | *Total n* |
| AS | **C/r/V** | 26,6 | 64,6 | 8,6 | 0,1 | 5.755 | 28,3 | 36,8 | 19 | 15,9 | 129.534 |
| | **C/l/V** | 30,3 | 62,5 | 7,1 | 0 | 963 | 41,9 | 31,9 | 26,2 | 0 | 12.781 |
| CDS | **C/r/V** | 34,9 | 53,6 | 11,4 | 0,2 | 1.297 | 34,6 | 32,2 | 23,4 | 9,7 | 18.874 |
| | **C/l/V** | 38,9 | 51,3 | 9,8 | 0 | 162 | 53,9 | 33,6 | 12,5 | 0 | 11.111 |
| CS | **C/r/V** | 43,3 | 44,8 | 11,6 | 0,4 | 545 | 36 | 30,4 | 27,7 | 5,9 | 7.169 |
| | **C/l/V** | 40,5 | 47,6 | 11,9 | 0 | 84 | 62,6 | 30,3 | 5,3 | 0 | 393 |

**Table 2:** Type-Token frequency of CCV – by stress and liquid segment

Table 1 shows that, on average, 12% of the total types and 5% of the total tokens in maternal speech contain CCV syllables – a proportion similar to the approximately 17% types and 7% tokens observed in the Adult Speech. The similarity in the proportion of CCV syllables present in Child-Directed Speech, collected in situations of spontaneous interactions between caregivers and children, and in Adult Speech, collected in sociolinguistic interviews, indicates that the linguistic environment available to the child and the language model directed at them do not tend to avoid late-acquired linguistic structures, such as CCV. This suggests that Child-Directed Speech can be considered a regular sample of the target system being acquired.

Regarding Child Speech, only 622 words containing CCV targets were collected (no matter how they were pronounced) – a percentage of just 0.6% of the data, significantly lower than that observed in Child-Directed Speech and the Adult Speech. However, the percentage of CCV tokens, approximately 4%, differs little from the 5% observed in Child-Directed Speech, indicating that although the linguistic diversity of the child's vocabulary is drastically lower than that of their caregivers, the overall use of words containing CCV syllables is quite similar – suggesting that the same words are repeated more frequently in Child Speech than in Adult Speech. Table 2 shows that the majority of those words present CCV in unstressed positions, mainly

[1] The corpora can be found on the following addresses: https://leal.fflch.usp.br/Corpora-FI-FDC, https://github.com/SauronGuide/corpusABG.

with the C/ɾ/V segmental combination.

To analyze how phonologically dense the CCV neighborhood is in the input available to children in BP, we conducted a count of minimal pairs of the CCV-CV type (such as *freio* ‘brake device’ *vs. feio* ‘ugly’, *flocos* ‘flake’ *vs. focos* ‘focus’) and the C/l/V-C/ɾ/V type (such as *inflação* ‘inflation’ *vs. infração* ‘infraction’) in the corpora FA (Adult Speech), FDC (Child-Directed Speech), and FI (Child Speech). For this purpose, we used the PCT software (Phonological Corpus Tools). Table 3 quantifies the pairs obtained:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **CCV Phonological Density** | | | | | | | | | | | |
| *Adult Speech (ABG Corpus, Benevides & Guide, 2017)* | | | | | | | | | | | |
| /pɾV/-/pV/ | 52 | /plV/-/pV/ | 18 | /bɾV/-/bV/ | 43 | /blV/-/bV/ | 0 | /pɾV/-/plV/ | 2 | /bɾV/-/blV/ | 2 |
| /tɾV/-/tV/ | 78 | /tlV/-/tV/ | 1 | /dɾV/-/dV/ | 3 | /dlV/-/dV/ | 0 | /tɾV/-/tlV/ | 0 | /dɾV/-/dlV/ | 0 |
| /kɾV/-/kV/ | 21 | /klV/-/kV/ | 16 | /gɾV/-/gV/ | 15 | /glV/-/gV/ | 1 | /kɾV/-/klV/ | 2 | /gɾV/-/glV/ | 0 |
| /fɾV/-/fV/ | 26 | /flV/-/fV/ | 9 | /vɾV/-/vV/ | 5 | /vlV/-/vV/ | 0 | /fɾV/-/flV/ | 3 | /vɾV/-/vlV/ | 0 |
| TOTAL: 288 CCV-CV pairs; 9 C/l/V-C/ɾ/V pairs | | | | | | | | | | | |
| *Child Directed Speech (FDC Corpus, Santos & Toni, 2020)* | | | | | | | | | | | |
| /pɾV/-/pV/ | 17 | /plV/-/pV/ | 3 | /bɾV/-/bV/ | 5 | /blV/-/bV/ | 0 | /pɾV/-/plV/ | 0 | /bɾV/-/blV/ | 0 |
| /tɾV/-/tV/ | 16 | /tlV/-/tV/ | 0 | /dɾV/-/dV/ | 1 | /dlV/-/dV/ | 0 | /tɾV/-/tlV/ | 0 | /dɾV/-/dlV/ | 0 |
| /kɾV/-/kV/ | 2 | /klV/-/kV/ | 4 | /gɾV/-/gV/ | 0 | /glV/-/gV/ | 0 | /kɾV/-/klV/ | 0 | /gɾV/-/glV/ | 0 |
| /fɾV/-/fV/ | 9 | /flV/-/fV/ | 4 | /vɾV/-/vV/ | 0 | /vlV/-/vV/ | 0 | /fɾV/-/flV/ | 0 | /vɾV/-/vlV/ | 0 |
| TOTAL: 61 CCV-CV pairs; 0 C/l/V-C/ɾ/V pairs | | | | | | | | | | | |
| *Child Speech (FI Corpus, Santos & Toni, 2020)* | | | | | | | | | | | |
| /pɾV/-/pV/ | 8 | /plV/-/pV/ | 2 | /bɾV/-/bV/ | 4 | /blV/-/bV/ | 0 | /pɾV/-/plV/ | 0 | /bɾV/-/blV/ | 0 |
| /tɾV/-/tV/ | 6 | /tlV/-/tV/ | 0 | /dɾV/-/dV/ | 0 | /dlV/-/dV/ | 0 | /tɾV/-/tlV/ | 0 | /dɾV/-/dlV/ | 0 |
| /kɾV/-/kV/ | 1 | /klV/-/kV/ | 1 | /gɾV/-/gV/ | 0 | /glV/-/gV/ | 0 | /kɾV/-/klV/ | 0 | /gɾV/-/glV/ | 0 |
| /fɾV/-/fV/ | 2 | /flV/-/fV/ | 2 | /vɾV/-/vV/ | 0 | /vlV/-/vV/ | 0 | /fɾV/-/flV/ | 0 | /vɾV/-/vlV/ | 0 |
| TOTAL: 26 CCV-CV pairs; 0 C/l/V-C/ɾ/V pairs | | | | | | | | | | | |

**Table 3:** Minimal pairs count between CCV-CV e C/l/V-C/ɾ/V in the corpora[2]

First addressing the CCV-CV density, Table 3 shows that the minimal pairs are concentrated in obstruent+rhotic combinations across the three corpora: while Adult Speech presents 243 C/ɾ/V pairs, there are only 45 C/l/V pairs; in Child-Directed Speech, 50 pairs consist of the flap (/ɾ/), compared to 11 with the lateral (/l/); and in Child Speech, there are 21 C/ɾ/V pairs and only 5 C/l/V pairs. Thus, the higher frequency of types and tokens for C/ɾ/V is also reflected in a denser lexical network.

However, this density is not evident when we analyze the segmental tier of CCV: there are only 9 C/ɾ/V-C/l/V minimal pairs in adult speech, and none in Child-Directed Speech and Child Speech. In comparison, for simple onsets Agostinho, Soares & Mendes (2020) found 1,334 pairs (such as *Ve**ra*** ‘woman’s name’ *vs. ve**la*** ‘candle’, ***ara**do* ‘plow’ vs. ***ala**do* ‘winged’) in another corpus of adult speech. Thus, there is a major difference in density between liquids in simple and in branching onsets. We argue that such a big difference in density between simple and branching onsets could wrongly inform the child’s system that there is a contrast neutralization between laterals and flaps in CCV (which indeed is found in some dialects in BP).

A question that arises regarding the phonological density of CCV is its distribution in the input: is the occurrence of CCV-CV pairs early in the child's linguistic environment? Furthermore, are CCV targets early in children’s vocabulary, or do words containing CCV concentrate in a later lexical stage? To address these points, we present Tables 3, which represent a method for quantifying the linguistic stimulus received by the child based on the most frequent types directed to them (YANG, 2016). In Table 4, the second, third, and

[2] Unlike Agostinho, Soares & Mendes (2020), our minimal pair count does not use lemmatized data, so we could also gather pairs generated by verbal or nominal inflections, such as in *complete* ‘to complete-PRESENT’ *vs. compete* ‘to compete-PRESENT’ (which would not be considered a pair in their lemmatized form, *completar* ‘to complete’ *vs. competir* ‘to compete’). This implies a quantitative advantage: more pairs are expected in our non-lemmatized count. Even so, the CCV-CV and C/l/V-C/ɾ/V pairs are significantly fewer than /l/V-/ɾ/V pairs.

fourth columns indicate the total number of CCV, V, and CV structures contained in the most frequent types used in Child-Directed Speech, up to the mark of the 6,000 most frequent words. These marks ideally represent the stages of the child's receptive vocabulary:

| **Most frequent types** | **CV** | **V** | **CCV** |
|---|---|---|---|
| **50** | 54 | 21 | **1** |
| **100** | 119 | 30 | **5** |
| **200** | 280 | 53 | **11** |
| **300** | 471 | 75 | **23** |
| **500** | 849 | 108 | **50** |
| **750** | 1.363 | 161 | **84** |
| **1000** | 1.896 | 225 | **109** |
| **1500** | 3.012 | 339 | **172** |
| **3000** | 6.165 | 717 | **333** |
| **6000** | 12.862 | 1.641 | **719** |

**Table 4:** Quantification of the most frequent types containing CCV, V, and CV in Child-Directed Speech

Following Yang 2016 method, Table 4 represents an approximate quantification of the positive evidence available to the child in the most frequent words of their linguistic environment. The discrepancy in children's exposure to CCV is evident: while a significant portion of the 50 most frequent words directed to children contain one or more CV syllables, and about half contain V syllables, only 1 word contains a CCV syllable — namely, the function word *pra* ‘to/for’, which is highly susceptible to reduction processes. Expanding the set to the 100 most frequent words directed to children, the first content words appear: *brincar* ‘to play’, *outro* ‘other’, *outra* ‘other, feminine’, and *pronto* ‘ready’. However, the first nouns and adjectives only emerge among the 200 most frequent words, with items such as *livro* ‘book’ and *grande* ‘big’. Even when considering the largest set of words in the table (6,000), it is notable that V syllables represent more than double the number of CCVs, and CVs occur almost twenty times more frequently than CCVs. This may explain not only the late acquisition of CCV but also the early acquisition of V in Portuguese (in addition to the salience factor pointed out by Freitas et al., 2006).

A second point to highlight in the above quantification lies in the functional load observed for the CCV structure in the language: while it is possible to collect V-CV pairs as early as the first 50 most frequent words in Child-Directed Speech, such as *que* ‘what’ *vs. e* ‘and’, *na* ‘in the’ *vs. a* ‘the’, *aí* ‘there’ *vs. aqui* ‘here’, *é* ‘is’ *vs. né* ‘right’—pairs that demonstrate the contrastive value of syllable structures through the addition/subtraction of sounds—the first CCV~CV pair observed in our Child-Directed Speech corpus only appears among the 400 most frequent words, with items such as *tem* ‘it has’ *vs. trem* ‘train’ and *for* ‘go-PAST’ *vs. flor* ‘flower’, totaling only 61 pairs of this type in the entire FDC Corpus. These data illustrate that the contrastive value of CCV does not seem to be readily apparent to the child from the earliest stages of their phonological development.

In addition to the low frequency and low phonological density, Miranda & Cristófaro (2013), and Oliveira (2017) also observe variability in the production of CCV targets. Their studies note that, despite the phonological distinction between CCV and CV, some dialects allow the reduction CCV→CV, particularly in unstressed contexts, as in *re[fɾi]gerante ~ re[fi]gerante* ‘soda’, *li[vɾʊ] ~ li[vʊ]* ‘book’, *[pɾo]fessora ~ [po]fessora* ‘teacher’, *[pɾo]blema ~ [po]blema* ‘problem’. Unlike other sociolinguistic processes affecting CCV, such as transposition (*vid[ɾ]o ~ v[ɾ]ido* ‘glass’) and metathesis (*p[ɾ]ocurar ~ po[ɾ]curar* ‘to search’, *pe[ɾ]gunta ~ p[ɾ]egunta* ‘question’), CCV reduction is not socially marked, occurring in adult speech regardless of age, gender, and educational level, with only the stress context acting as a conditioning factor (Oliveira, 2017). The reverse process, CV → CCV, also exists in BP (although with very low frequency, as it applies only in words with antepenultimate stress), generating occurrences such as *[ˈʃi.kɐ.ɾɐ] > [ˈʃi.kɾɐ]* ‘cup’, *[ˈɔ.kʊ.lʊs] > [ˈɔ.klʊs]* ‘glasses’ (which represent 1.4% of the corpus, according to of Araújo et al., 2007). In Table 5, we observe that the simplification of branching onsets primarily applies in post-tonic contexts and in unstressed functional words in Adult Speech and Child-Directed Speech:

| | | Pretonic | Stressed | Posttonic | Functional words |
|---|---|---|---|---|---|
| **AS** | CCV → CV | 2,29% | 0,21% | 16,67% | 22,11% |
| | Total tokens | 1.791 | 1.437 | 1.092 | 873 |
| **CDS** | CCV → CV | 0% | 0% | 15,5% | 23,5% |
| | Total tokens | 50 | 70 | 45 | 64 |

**Table 5:** Quantification of CCV→CV reduction in Adult Speech and Child-Directed Speech

Therefore, some occurrences of branching onsets in the target language may undergo reduction in adult speech, appearing sometimes as CCV and other times as CV, in a process of structural neutralization. Interestingly, the neutralizable contexts of CCV stand out among the most frequent examples of branching onsets in Child-Directed Speech. The question that arises from these data, which contrast the abundance observed in CV with the low phonological neighborhood and variability of CCV, is: Could the contextual neutralization of contrasts found on the unstressed CCV reduction in adult speech affect the acquisition of CCV-CV contrast in BP? How might the low phonological neighborhood affect the specification of words containing CCV? And how are children's production and perception influenced by it? Although there are invariant contexts available in the language for determining the CCV-CV contrast—such as stressed syllables—would these contexts be sufficient to establish the contrast observed in the target system, outweighing the CCV~CV variation that occurs in unstressed contexts (which are more frequent than the stressed ones)? To answer these questions, we present the following experimental study.

## 3 Experimental study: picture-naming and mispronunciation detection task

Summarizing our corpora research, the CCV syllable type in BP shows low type-token frequency in the input (both in adult speech and child directed speech), is highly concentrated into C/ɾ/V segmental patterns (in despite of C/l/V), and present low-density phonological neighborhoods, both when comparing CCV-CV and C/l/V-C/ɾ/V. However, when comparing the same /l, ɾ/ segments in simple CV onset position, the input shows high phonological density. We argue that this discrepancy could lead to an incorrect hypothesis of /l/-/ɾ/ contrast neutralization in CCV syllables by the child’s developing phonological system. Contrast neutralization is also observed in the syllable structure: unstressed CCV syllables are susceptible to optional CCV→CV reduction in adult speech. Paired with the low density observed between CCV and CV structures, we argue that this process could also lead to an incorrect hypothesis of CCV-CV neutralization by the child’s developing grammar. On top of that, in child directed speech (CDS) reducible CCV contexts are highly early and frequent, but the first CCV-CV minimal pair is found only between the 400 most frequent words. Also, only 6% of the 50 most frequent CDS words represent the C/l/V pattern. No minimal pairs between C/ɾ/V and C/l/V were found in CDS, whereas /ɾ/V-/l/V pairs were found between the 300 most frequent words.

Such input properties may lead to (i) an incorrect structural neutralization, taking CV as a free alternating form of CCV; (ii) an incorrect segmental neutralization, taking /l/ and /ɾ/ as not contrastive in CCV contexts. That is, children might be overgeneralizing contrast neutralization rules based on the distributional properties of their early stages of vocabulary. Therefore, we argue that the establishment of the phonological contrast of CCV-CV and of C/ɾ/V-C/l/V are the causes for the long-lasting phonological development of CCV syllables in BP.

To test the hypothesis of structural and segmental overneutralization, a picture naming and a mispronunciation detection task were carried out with 71 children between 2;0-5;11 years old (15-20 children per age group). The production experiment included tasks of spontaneous naming and repetition, with 74 words containing C/l/V and C/ɾ/V (prosodic template ˈCCV.CV, such as *bruxa* ‘witch’ and *blusa* ‘shirt’), as well as control words with /l/ and /ɾ/ in CV onsets (prosodic template CVˈCV.CV,[3] such as *coruja* ‘owl’ and *galinha* ‘chicken’). The mispronunciation detection task comprised 2 experimental conditions: structural condition, consisting of stimuli with liquid insertion (CV → CCV), which aim to observe whether children recognize CCV and CV syllables as distinct; CCV reduction (CCV→CV) forming another existing word in the language; and CCV reduction (CCV→CV) which do not form another word in BP (which were designed to check the role of phonological density in lexical recognition); and segmental condition, consisting of

[3] The same prosodic template could not be maintained in the control stimuli since /ɾ/ do not occur word-initially in BP.

stimuli with [l] ↔ [ɾ] change in CCV; and [l] ↔ [ɾ] change in CV. Examples are provided below:

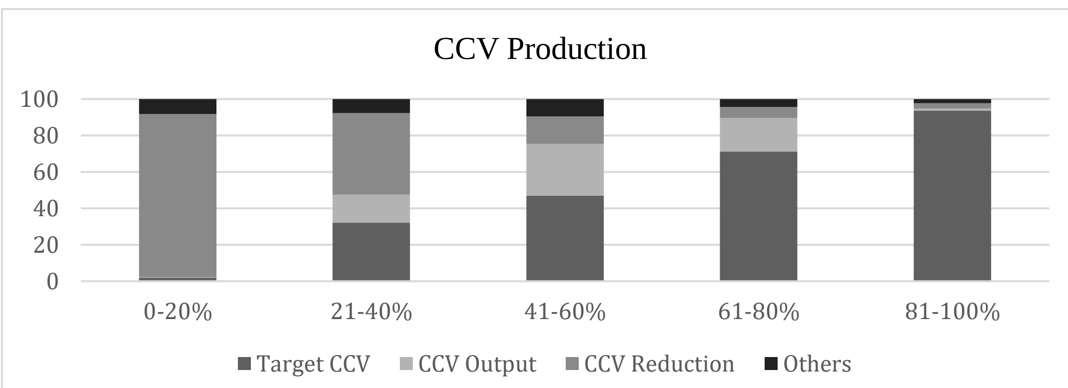
(1) **Structural condition:** are CCV and CV contrastive?
CV → CCV: /**pe**ʃi/ → *[ˈ**pre**.ʃɪ] 'fish'; /**do**si/ → [ˈ**dlo**.sɪ] 'candy'
CCV → CV (without changing the meaning): /**tɾa**vi/ 'goalpost' → *[ˈ**ta**.vɪ]; /**blu**za/ → *[ˈ**bu**.zɐ]
CCV → CV (causing a change in the meaning): /**pɾa**tu/ 'dish' → [ˈ**pa**.tʊ] 'duck'; /**pla**ka/ 'sign' → [ˈ**pa**.kɐ] 'paca (a specie of rodent animal)'

(2) **Segmental condition:** are /ɾ, l/ contrastive both in CCV and CV?
C[ɾ]V ↔ C[l]V: /**blu**za/ → *[ˈ**bɾu**.zɐ] 'shirt'; /**bɾu**ʃa/ → *[ˈ**blu**.ʃɐ] 'witch'
[ɾ]V ↔ [l]V: /ga**li**ɲa/ → *[gaˈ**ɾi**.ɲɐ] 'chicken'; /ko**ɾ**uʒa/ → *[koˈ**lu**.ʒɐ] 'owl'

Stimuli were presented using cards and puppets, contextualizing the task as a game in which the child would play the role of a teacher, correcting the errors of a puppet learning to speak. Following the methodological recommendations of Grolla (2009), both the correction of errors and the correct responses were accompanied by playful cues to avoid the child feeling embarrassed about correcting the puppet. The same children participated in both production and mispronunciation detection tasks (but only in one misperception condition, structural or segmental). Children's responses were recorded and acoustically verified.

Even though age was used as a reference for data collection, we emphasize that the criterion for organizing and analyzing the results was Task Performance (Toni & Santos, 2021). That is, for the analysis of the mispronunciation detection task we grouped children according to their own results on the production task. This criterion aims to group the productions of different children into homogeneous sets to enable appropriate inter- and intra-group comparisons. In the production test, children were grouped by their percentage of correct CCV productions (ranges 0-20%, 21-40%, 41-60%, 61-80%, 81-100%); in the detection task, children were regrouped based on their speech production patterns: systematic CCV→CV reductions (**group C0V**); production of C/l/V and absence of /ɾ/ in CCV and/or CV (**group C_V**); systematic exchanges between liquids in CCV (**group C?V**); stable CCV production (*Control group*).

Although not usual, organizing the data according to task performance criteria, like the percentage of correct CCV productions, allow researchers to observe that the type of repair strategies predominantly applied in each percentage range is distinct.[4] Children who produce only 0% to 20% of correct CCV targets predominantly simplify branching onsets into simple onsets; meanwhile, children who correctly produce CCV between 21%-80% predominantly use repair strategies modifying the consonantal quality of C2 and/or C1, keeping the branching onset structure. To illustrate this point, we present Graph 1:



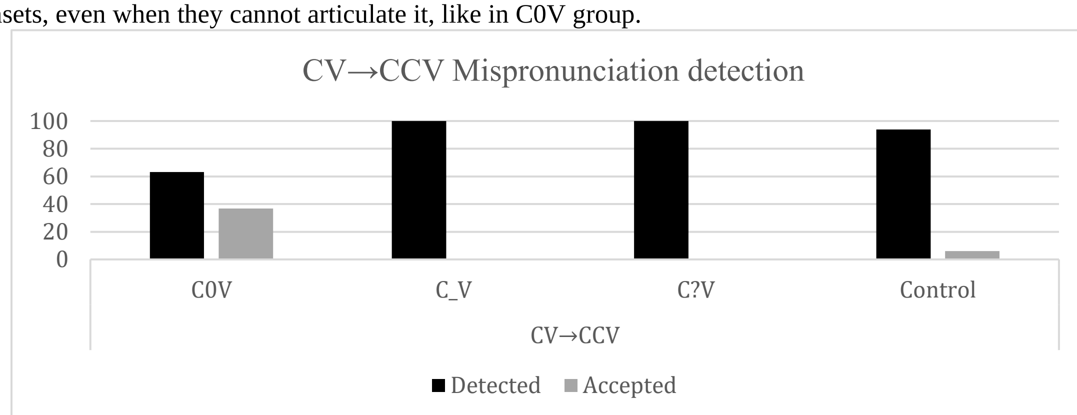

**Graph 1:** Children's CCV production patterns

Graph 1 presents, in the "Target CCV" label, productions that match the target form (e.g., /pɾato/ → [ˈpɾa.tʊ]). In the "Output CCV" label, it shows productions where the branching structure was kept, but its segmental quality was modified (e.g., /pɾato/ → [ˈpla.tʊ]). In the "CCV Reduction" label, we have realizations where CCV was simplified to CV (/pɾato/ → [ˈpa.tʊ]). Finally, in "Others" label, the remaining repair strategies observed are listed (epenthesis, metathesis etc). The graph indicates that CCV→CV reduction are

[4] For a comparison between age and task perfomance criteria applied to the same data, see Toni & Santos, 2021.

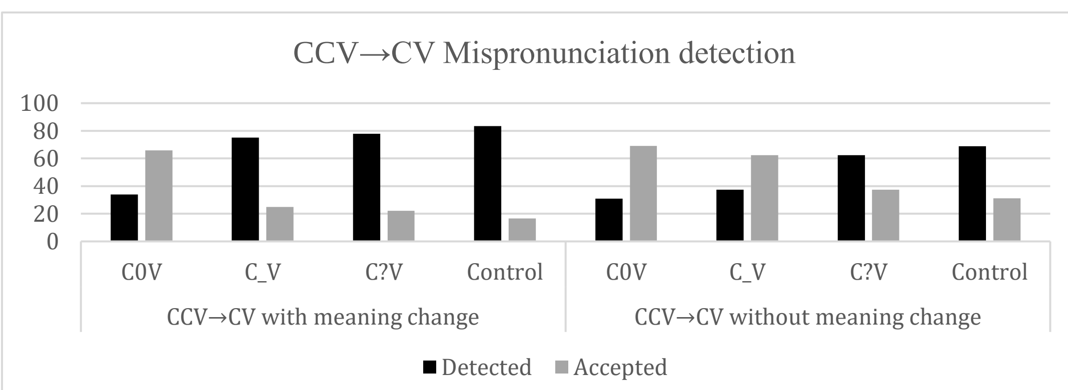
predominantly concentrated in the speech of children with the lowest correct production rates, 0%-20%. Thus, unlike the literature based on age ranges, it is noted that CCV reduction is not a generalized repair strategy but is instead concentrated at specific moments in linguistic development. What stands out in the graph is the increase in the "Output CCV" column between the 21%-40% and 61%-80% ranges—and particularly when observing the sum of the "Correct CCV" and "Output CCV" columns, it is evident that even the second group already has half of their CCV targets containing the branching structure, and the third group can be considered to have acquired the branching structure (but not their segmental combinations). This shows that different repair strategies are favored at specific moments in CCV development: in the early stages of production, CCV structure is absent from child speech; in the intermediate stages, CCV structure becomes increasingly present and productive. This growth in CCV outputs (with correct or incorrect consonantal quality) indicates that the CCV syllabic template is acquired before its segmental filters.

Looking at the mispronunciation detection results, we observe in Graph 2 that children readily detect occurrences of CV→CCV, indicating that they recognize the difference between simple and branching onsets, even when they cannot articulate it, like in C0V group.




**Graph 2:** CV → CCV mispronunciation detection

On the other hand, Graph 3 shows that children in the C0V group, who do not produce CCV in their speech, are unable to recognize instances of CCV→ CV reduction. As expected, children from the Control Group are able to detect the mispronunciations. Finally, children from the intermediate groups, C?V and C_V, who already have the branching syllabic structure in their system but substitute /ɾ, l/ in CCV, also detect occurrences of CCV→CV reduction. In other words, children recognize that CV cannot be replaced by CCV, although CCV can be replaced by CV—which points to the influence of phonological (rather than perceptual) factors in acquisition. These factors are further corroborated by the difference observed between the CCV→CV conditions with and without minimal pairs: errors that do not invade the phonological neighborhood of the word (i.e., those that cannot be confused with other words in the language, such as /**pre**to/ → *[ˈ**pe**.tʊ] 'black') are detected less often than reductions that create lexical confusion (such as /**pra**to/ 'dishplate' → [ˈ**pa**.tʊ] 'duck'), as predicted by Swingley & Aslin (2002).



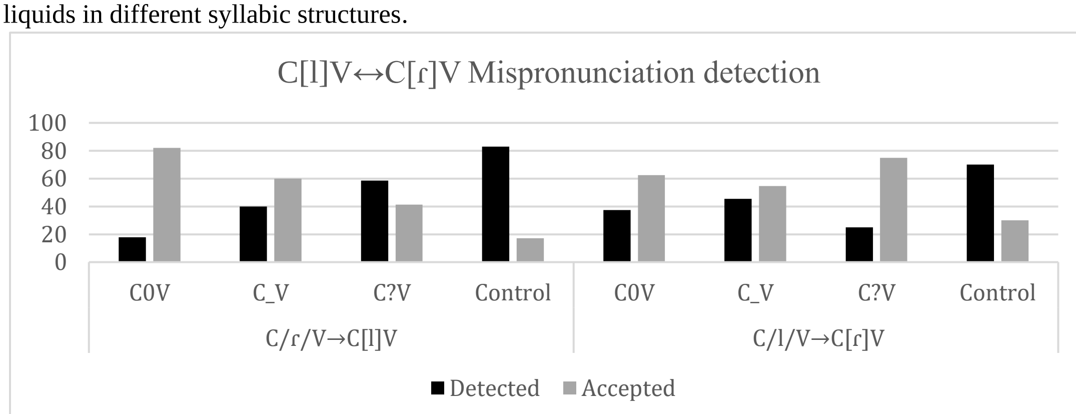

**Graph 3:** CCV → CV mispronunciation detection

Observing the detection pattern for words with minimal pairs (on the left in Graph 3), we note that only C0V group shows low rates of recognition for CCV→CV, suggesting that children who systematically produce CCV→CV in their speech do not yet recognize the phonological value of the C2 position in their lexical representations. However, these same children recognize the opposite CV→CCV substitution in Graph 2, indicating that the child perceives the acoustic difference between CCV and CV; their acceptance of CCV→CV reductions thus must occur at a phonological level.

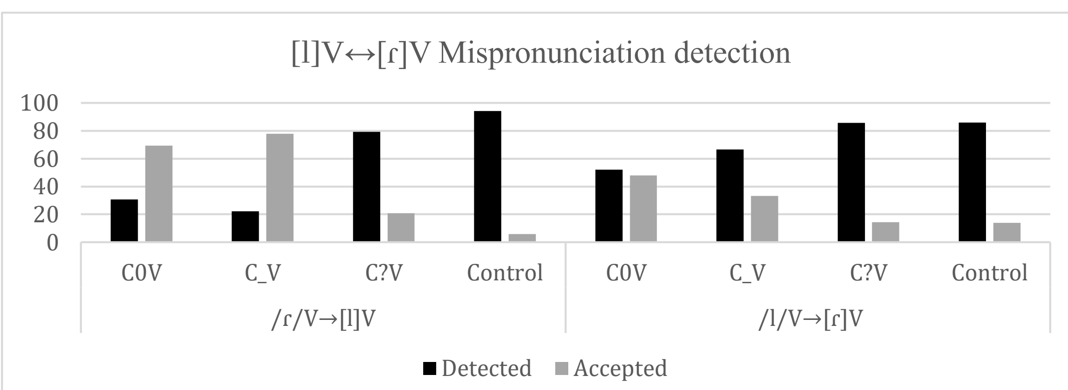
Still on the minimal pair condition (Graph 3, left), children in the C_V and C?V groups, who systematically substitute or delete one of the liquids in their productions, already demonstrate recognition of the C2 position in CCV. That is, even though the consonantal characteristics of this segment might not fully specified, the syllabic position C2 and, consequently, the branching onset, are already developed in their phonological system. It is worth noting, in particular, that both C_V and C?V exhibit similar structural behavior (even though C/ɾ/V is systematically absent in C_V, but not in C?V).

A different picture emerges when we observe the detection pattern for CCV→CV when minimal pairs are not formed (Graph 3, right): significant differences ($\alpha$=0.1) in CCV detection are observed in the Control group ($p < 0.01$) for stimuli such as /pɾato/ 'dishplate' →[ˈpa.tʊ] 'duck' *versus* /pɾaia/→*[ˈpa.jɐ]. In the C_V and C?V groups, it is observed that data with minimal pairs are detected more often than those that do not form minimal pairs. Our results suggest, therefore, that phonological density influences the specification of lexical information. Interestingly, a very similar detection proportion is observed between the conditions with minimal pairs (34%) and without minimal pairs (30.9%) in the C0V group ($p = 0.9006$), indicating that, unlike children in the C_V and C?V groups and the Control group, the factor of phonological density does not yet exert influence on the system of children with very incipient CCV development.

Finally, to analyze the influence of the liquids, considering the difference in the phonological density between /l, ɾ/ in CCV and CV syllables, let us examine Graphs 4 and 5. To discuss the segmental results, we will draw two comparisons: the behavior of the different directions of liquid substitution; and the behavior of liquids in different syllabic structures.




**Graph 4**: C[ɾ]V ↔ C[l]V mispronunciation detection




**Graph 5**: [ɾ]V ↔ [l]V mispronunciation detection

Examining the behavior of liquids in Graphs 4 and 5, let us first look at the extreme groups: in the C0V group, we find the lowest rates of error detection, especially in the direction [flap]→[lateral], both in CCV and CV. Children who do not produce liquids in their branching onsets – and who also mostly lack them in simple onsets – thus seem unable to detect segmental substitutions in these syllabic positions. On the other hand, the Control group, as expected, exhibits the opposite behavior: productive detection of substitutions [l]↔[ɾ] in both CCV and CV.

Now, let us examine the behavior of the intermediate groups, C_V and C?V, which show distinct proportions of detection for substitutions [flap]→[lateral] and [lateral]→[flap]. Children in the C_V group do not produce the flap in CCV or CV but do productively produce the lateral liquid in both syllabic positions. Interestingly, the detection pattern of the C_V group reflects this production pattern: the children do not seem to detect the difference between /ɾ/V→[l]V, which aligns with their speech repairs, nor the difference between C[l]V↔C[ɾ]V; however, the opposite direction, which leads to the segment not yet acquired by the child, /l/V→[ɾ]V, is recognized, with a significant difference ($p < 0.06$) in the detection values [l]V↔[ɾ]V. As for the C?V group, these are children who systematically swap the quality of liquids in CCV but do not fail to produce the branching structure C1C2; in CV, the liquids are fully acquired. In the detection patterns of this group, we observe that in CV, both directions of liquid substitution are detected, as in the Control group. The same does not apply to the CCV context: there are significant differences ($p < 0.09$) in the recognition of C/ɾ/V→C[l]V, which is more detected than the opposite direction, C/l/V→C[ɾ]V.

Moving on to examine the relationship between syllabic structure and the detection of liquid quality, let us now compare the behavior of /ɾ, l/ in CCV versus CV. Here, we draw attention again to the behavior of the intermediate C?V group: unlike the C0V and C_V groups (which do not have all liquids acquired in CV), children in the C?V group show significantly distinct detection patterns depending on the type of syllable in which the liquid is inserted. For example, while modifications such as b/l/usa→b[ɾ]usa are recognized in 25% of their occurrences, substitutions in CV like ga/l/inha→ga[ɾ]inha are detected in over 85% of the targets ($p < 0.001$) by the same children. The opposite segmental direction, p/ɾ/ato→p[l]ato and co/ɾ/uja→co[l]uja, also shows an important difference in its detection rates (though not significant, $p = 0.19$). These results indicate that the same segmental substitution presents different detection rates on distinct syllabic contexts.

In this comparison, even the Control group shows significant differences: substitutions [l]↔[ɾ] are more detected in CV than in CCV for both consonantal directions. And although not significantly, even the C0V and C_V groups show an increase in CV detection compared to CCV – especially when the modifications transform the lateral, their more stable liquid, into a flap. These results thus point to an effect of syllabic structure on the detection of consonantal quality. In other words, the detection of the same segmental substitution varies depending on the type of syllable in which the segment is inserted.

## 4 Modelling the data

Having described the patterns observed in the input and in children's production and detection, let us now move on to discuss how and why the CCV syllable is acquired in the way it is in BP.

Part of the occurrences of branching onsets in the target language may undergo reduction in adult speech, in a process of structural neutralization. Interestingly, the neutralizable contexts of CCV stand out among the most frequent examples of branching onsets in child-directed speech (CDS). To verify whether the variable unstressed data are sufficient to trigger a generalization, reclassifying CV as a variant form of CCV in all stressed contexts, let us apply Yang's Tolerance Principle (2016), which determines the threshold of exceptions a system can tolerate.

The Tolerance Principle (YANG, 2016) deals with how the contrastive value between two varying structures, like the CCV/CV production, are built in the linguistic system. It assumes that there is a tipping point of exposure that leads to the generalization of a variation. This tipping point is ruled by an equation[5] and is measured by quantifying how many varying items exist in the input's most frequent words (N). Table 6 shows that the high concentration of variable CCVs in CDS initially goes over the tolerable tipping point ($\theta N$). Therefore, only with bigger vocabularies (bigger Ns) children should be able to realize the contrast between CCV and CV.

[5] Tolerance Principle: R is a rule applicable to N items, of which e are exceptions. R is productive if and only if $e \leq \theta N = N/\ln(N)$.

| TYPES | Stressed CCV | Unstressed CCV | TOTAL CCVs (N) | Varying CCV→CV (e) | $\theta_N$ | Is the variation tolerable? |
|---|---|---|---|---|---|---|
| 50 | 0 | 1 | 1 | 1 | - | - |
| 100 | 1 | 4 | 5 | 3 | 3,1 | ? |
| 200 | 3 | 8 | 11 | 7 | 4,6 | NO |
| 300 | 6 | 17 | 23 | 10 | 7,3 | NO |
| 500 | 22 | 28 | 50 | 13 | 12,8 | NO |
| 750 | 38 | 46 | 84 | 16 | 19,0 | YES |
| 1000 | 50 | 59 | 109 | 20 | 23,2 | YES |
| 1500 | 81 | 91 | 172 | 25 | 33,4 | YES |

**Table 6:** Applying the Tolerance Principle

Table 6 is constructed based on the assumption that, initially, the Transparency Hypothesis (Ringe & Eska, 2013) must be followed—that is, at first, the underlying form of words is mapped directly to their surface form, [CCV]=/CCV/ and [CV]=/CV/. However, the occurrence of CCV→CV reductions in input words like [ˈo.tɾʊ] ~[ˈo.tʊ], [pɾa]~[pɐ], and [pɾeˈsi.zɐ]~[pˈsi.zɐ] constitutes an exception to the one-to-one mapping [CCV]=/CCV/, as it implies that [CV]=/CCV/. The high concentration of contexts where [CV] phonologically equals /CCV/ at certain stages of the child's receptive vocabulary forces the abandonment of transparency, allowing [CV] as an alternating form of all /CCV/ occurrences, whether reducible or not in the target (stressed or unstressed). It is only with the growth of vocabulary that exceptions become tolerable again, as new words containing non-reducible CCVs are added to the child's lexicon. In order to acquire CCV, children need to establish CCV's phonological value, ultimately assuming that /CCV/→[CV] are exceptions to the transparent value of /CCV/→[CCV].

Data presented in Table 6 justify, via the Tolerance Principle, the occurrence of CV variants as variable forms of CCV (similarly to allophones, in the absence of a more appropriate term) in the early stages of syllabic acquisition, based on the generalization of the CCV→CV reduction process. To verify whether this overgeneralization hypothesis is empirically confirmed, let us return to our experimental results. The production and mispronunciation detection tasks indicate that CCV is a structure that emerges early in the child's linguistic system, initially being simplified to CV in speech production, although children already demonstrate the ability to perceive the difference between CCV and CV, recognizing that CV is an acceptable candidate for the CCV structure, but CCV is not an acceptable alternative to CV.

By considering that the child assumes the difference between CCV and CV as optionally non-contrastive, we can explain why children in the C0V group do not detect CCV→CV occurrences, although they detect the opposite direction, CV→CCV. That is, children perceive the difference between CCV and CV and recognize that these structures are equivalent in specific contexts—it is possible to find a CV variant of CCV in the target language, but the opposite does not apply. The overgeneralization of the CCV~CV variation context also explains why remnants of the CCV→CV reduction persist even in the speech of children who have already acquired the CCV structure. It also explains the low rate of use of repair strategies classified as "Others" in Graph 1, such as epenthesis and metathesis: CV.CV and CVC structures are not common alternatives to CCV in BP because there is no avoidance of the CCV structure *per se*, but rather a failure to recognize that the CCV~CV variation is restricted to specific prosodic contexts.

Furthermore, the absence of the phonological neighborhood influence in the C0V group is also an indication that, at this initial stage, the system has not received sufficient unambiguous cues about the CCV-CV contrast, still working productively with the generalization of structural neutralization. However, as more cues about contrast are gathered, the system begins to recognize the phonological value of CCV and the restriction on CCV~CV variation. Schematically, then, we have a U-shaped curve:

Moment 1: Surface form = Underlying form (CCV ≠ CV in Phonology)
Moment 2: Generalization of variation (CCV = CV in Phonology)
Moment 3: Recognition of contrast (CCV ≠ CV in Phonology)

In Moment 1, CCV and CV are distinct due to the action of the Transparency Hypothesis—and here we cannot rule out the existence of a Moment 0, representing the absence of the CCV syllabic structure in the system. Moment 2 of CCV acquisition is consistent with a high number of /CCV/=[CV] data, causing a reanalysis of the child's initial hypothesis (the default that surface differences translate into differences in underlying representation). The transition to Moment 3 occurs when the lexicon becomes denser, with more words containing non-variable CCVs in the input, as well as CCV-CV minimal pairs.

Regarding the segmental tier of CCV, we propose that the discrepancy between the frequency bias of /l, ɾ/ in CCV versus the balanced frequency of /l, ɾ/ in CV, as well as the scarcity of minimal pairs C/l/V-C/ɾ/V compared to the abundance of minimal pairs /l/V-/ɾ/V, lead to a point in the acquisition process where the contrastiveness of /l/-/ɾ/ is recognized in CV but not in CCV. The results of the detection test pointed to differences in the recognition of segmental substitutions between the liquids /l, ɾ/ conditioned by the syllabic context: substitutions in simple onsets are more detected than the same substitutions in complex onsets. This indicates that what allows the acceptance of the errors is not a segmental factor but rather a phonotactic one, conditioned by the syllabic context – a finding that is further corroborated by the different detection patterns demonstrated by each of the syllabic development groups: the more incipient the phonotactic acquisition, the fewer detections are observed.

In other words, the ability to detect errors involving /l/ and /ɾ/ is influenced by the syllabic structure in which these liquids appear. This suggests that the acquisition of contrastiveness between /l/ and /ɾ/ is not solely a matter of segmental differentiation but is also deeply tied to the development of phonotactic knowledge. As children progress in their ability to produce and perceive complex syllabic structures, their sensitivity to segmental contrasts within those structures also improves. This highlights the interplay between segmental and syllabic development in phonological acquisition.

## 5 Final remarks

Our goal in this research was to better understand how branching onsets are systematized in the child's phonology throughout their linguistic development. The answers we arrived at point to the fundamental role of contrast in the construction of the language's phonology—thus harkening back to classics like Jakobson and Saussure.

The examination of input characteristics and our experimental data indicated that in the acquisition of branching onsets, the combined action of CCV~CV variability, the low phonological density of CCV-CV and of C/l/V-C/r/V, compared to the high density of /l/V-/r/V, leads to an incorrect generalization of CV as a possible phonetic form of CCV, and [l] as a possible phonetic form of /r/ in CCV, but never in CV. Accordingly, our experimental results show that contrastive relations are a key point in the development of branching onsets. We thus argue that there is a moment in child development when simple onsets are taken as an alternative form of branching onsets (but never the opposite), and the contrastivity between /l, ɾ/ depends on their syllable context. In sum, the experimental study suggests that CCV acquisition in BP goes through a moment of incorrect structural and segmental contrast neutralization caused by an overgeneralization of input distributional patterns, therefore why CCV production takes so long to stabilize in child speech in this language. The acquisition path thus involves not only the development of the CCV structure and its segmental filters but also the mastery of the phonological processes active in the target language and their contexts of application.

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