MASTER IN COGNITIVE SCIENCE AND LANGUAGE

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Acquisition of complex syllabic onsets in Catalan children

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Abstract

The acquisition of complex onsets in word-initial position has been an area of interest in the field of phonological acquisition. The aim of this MA thesis is to offer an account of word-initial complex onset production in Catalan children, based on the work by Jongstra (2003) for Dutch framed within Optimality Theory. The empirical base of the study is an elicitation task administered to 27 children acquiring Catalan between the ages of 2;2 and 3;3. The story featured 3 items for each voiceless word-initial consonant cluster in Catalan (namely [pɾ, pl, tɾ, kɾ, kl, fɾ, fl]). The results of the experiment show that Catalan children present a consistent pattern of cluster reduction to C1, contrasting with the patterns observed for Spanish and Dutch children. In addition, the experiment reveals that there is a hierarchy regarding the acquisition of word-initial CCs, greatly influenced by the relative sonority between the consonants in the cluster, favoring the production of clusters where the distance in sonority is higher. However, production of word-initial CCs is not within-cluster stable, showing that different mechanisms of word-initial CC production coexist in the language of the same child, at least for a period of time. Another innovation of the present thesis is that it considers the effect of frequency of the target word-initial CCs in language acquisition. The results indicate, however, that frequency does not play a relevant role in complex onset acquisition, whereas relative sonority does.

Keywords: consonant cluster, complex onset, language acquisition, phonology, Catalan

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1 INTRODUCTION

The acquisition of complex onsets in word-initial position has been an area of interest in the field of phonological acquisition. Despite the prominence onsets have in the syllabic structure, authors such as McLeod et al (2001) have reported that typically developing children do not start producing adult-like consonant clusters (CC) until age 2, although other authors have found word-initial CC productions at 1;10 (Lleó & Prinz 1996: 54). The aim of this MA thesis is to offer an account of word-initial complex onset production in Catalan children, based on the work by Jongstra (2003) for Dutch. The scope of the thesis is restricted to consonant clusters in which C1 is voiceless and revolves around children between ages 2 and 3.

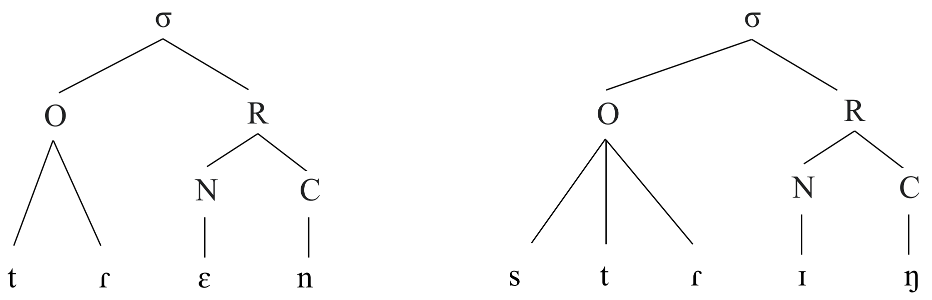
The thesis is organized as follows: in §1 I offer an overview of complex onsets cross-linguistically (§1.1) and their distribution in Catalan (§1.2). §2 deals with two proposals to account for patterns of complex onset acquisition within Optimality Theory (OT; McCarthy & Prince 1995, Prince & Smolensky 1993). These are the works of Pater & Barlow (2002) (§2.1) and Jongstra (2003) based on Goad & Rose (2004) (§2.2). In §3 the research questions for the study are presented. §4 describes the experimental study conducted and the results are presented in §5. §6 deals with the discussion of the findings and the conclusions are collected in §7.

1.1 General patterns of complex onsets across languages

Word-initial complex onsets consist of two or more consonants preceding the nucleus of the syllable. Clusters of up to three consonants have been attested cross-linguistically, as exemplified in (1a,b) for Catalan and English, respectively.

(1) Word-initial syllables with complex onsets

a. CC- *tren* 'train' b. CCC- *string*



A relevant principle governing syllabic structure in natural languages is the Sonority Sequencing (Clements 1990), which in OT has been translated into a markedness constraint (SONSEQ), according to which the segments at the syllable boundaries must be less sonorous than the segments closer to the syllable nucleus. The definition of SONSEQ is given in (2) (from Wheeler (2005: 79)).

(2) SONSEQ: sonority must increase from the beginning of an onset to the nucleus of a syllable, and must decrease from the nucleus to the end of the syllable, where the scale of sonority is:
Stops < Fricatives < Nasals < Liquids < High vocoids < Non-high vocoids

As a constraint, SONSEQ can be violated, producing outcomes such as the English *string* in (1b), where the fricative /s/ violates the markedness constraint in preceding the stop /t/ with lower sonority.

Cross-linguistically, there are languages that have a higher frequency of CCs. Complex onsets are common in languages such as English, where one third of monosyllabic words have an initial consonant cluster, whereas only a 13% of natural languages never have consonant clusters in initial position (Locke 1983). The range of possible onset CCs also varies across languages. Languages such as Dutch have 23 possible word-initial CCs (Jongstra 2003), whereas languages such as Catalan have no more than 12 (or 17, if phonemic variation is included (e.g., [β] distinctly from [b]) (Timoneda 2021)). There seems to be a cross-linguistic restriction against coronal-coronal clusters that avoids */tl, dl/ (Bradley 2006:1)[1]. The clusters /tɾ, dɾ/, however, are attested in languages such as Catalan and Dutch, two languages that are compared in this thesis. The difference between /tl, dl/ and /tɾ, dɾ/ can be explained by arguing that while the lateral is specified as coronal, the rhotic is permanently unspecified for Place of Articulation (PA). Thus, in the clusters /tl, dl/ both consonants are identically specified as coronal, whereas in /tɾ, dɾ/ only the stop is specified as coronal, while the rhotic is unspecified for PA (see Goad & Rose 2004, Rice 1992).

1.2 Complex onsets in Catalan

In Catalan, word-initial complex onsets are limited to clusters of two consonants (C1C2). The most common type is that in which C1 is a stop or [f] and C2 a liquid, except for */tl, dl/, as discussed in the previous section. Written clusters from Greek, such as *ps-*, *pn-, pt, gn-* and *mn-* (*psicòleg* 'psyologist' *pneumatic* 'pneumatic', *pterina* 'pterin', *gnom* 'gnome'*, mnemotècnia* 'mnemonic'), are systematically reduced to C2. Since they are never produced as CC in adult language, clusters belonging to archaic forms have been left out of the scope of this paper. Finally, there are complex /s/C onsets, especially in words from languages such as English, which are systematically pronounced with an initial schwa (e.g., stop [əstɔ́p]), and therefore never emerge as a complex onset[2].

Of interest to the present study is the frequency of words with complex onsets in Catalan. Timoneda (2021) collected the entries in the *Diccionari de l'Institut d'Estudis Catalans* (*DIEC2*) to draw a picture of the existing onsets. The complex onsets in Catalan are summarized in (3), along with their frequency in *DIEC2*. Percentages are calculated

[1] This pattern has been interpreted in OT as the effect of a markedness constraint, Obligatory Contour Principle (OCP), which bans identically specified adjacent segments (see McCarthy 1986).
[2] For a more detailed discussion on epenthesis in Catalan, see §3.5.1 in Bonet & Lloret (1998), and Wheeler (2005) for an OT-based approach.

considering the total number of onset-initial words in *DIEC2* (n=43086) (data from Timoneda (2021)).

(3) Catalan complex onsets				*word count*	%
i.	Stop + [ɾ]	[pɾ]	(*prat* 'field')	1230	
		[bɾ]	(*brut* 'dirty')	534	
		[tɾ]	(*tren* 'train')	1031	
		[dɾ]	(*drac* 'dragon')	116	
		[kɾ]	(*cranc* 'crab')	500	
		[gɾ]	(*groc* 'yellow')	515	
		[fɾ]	(*fred* 'cold')	352	
		Total		4278	9.93%
ii.	Stop + [l]	[pl]	(*plàtan* 'banana')	464	
		[bl]	(*blau* 'blue')	138	
		[kl]	(*clau* 'key')	382	
		[gl]	(*gla* 'acorn')	231	
		[fl]	(*flor* 'flower')	293	
		Total		1508	3.5%

The recounts in (3) show that complex onsets with voiced stops are overall less frequent than their voiceless counterparts (e.g., there are 1230 words beginning with [pɾ] whereas only 534 begin with [bɾ]). In face of this, and considering the scope of this paper, only CCs where C1 is voiceless are dealt with henceforth. This means I focus on word-initial CCs with a frequency of a 9.87%, and a total of 4252 occurrences in *DIEC2.* The issue of complex onset frequency is retaken in §4.1 for the experiment design.

2 PREVIOUS WORK ON THE ACQUISITION OF COMPLEX ONSETS

Word-initial CCs have been found out to be a source of difficulty in early language productions (Gierut 1999). Complex onsets are acquired at later stages than complex codas, even though simple onsets have been argued to be acquired before simple codas, drawing an acquisition hierarchy of the syllabic structure as CV > CVC > CVCC > CCVCC (Lleó & Prinz 1996, Demuth & Kirk 2005). There are independent arguments that reinforce Lleó & Prinz (1996)'s hierarchy. On the one hand, the Onset Principle (avoid onset-less syllables) in OT can be argued to play a role in the early acquisition of CV syllables. On the other hand, the acquisition of complex codas before complex onsets is endorsed by the findings by Clements (1990), which show that there is a tendency in producing codas with a gradual fall of sonority, which is more easily granted by complex codas (VCC). In the case of onsets, however, Clements' results show a preference towards a sharp rise in sonority, which is more easily acquired with simple (CV) than complex onsets (CCV).

Initial studies that aimed to determine the age of production of the first correct complex onsets have set the earliest productions around 1;6 and 1;10, reporting a dramatic increase of correct productions around ages 2;2–2;5, falling from 93% child-like productions to 51% for German and Spanish (Preisser et al 1988, Lleó & Prinz 1996). However, other studies show that some 8- to 9-year-olds still have not mastered initial CC production for English (Smit et al 1990).

Strategies to avoid complex onsets have also been discussed in the literature (Smit 1993, Gilbers & den Ouden 1994, Gierut 1999, Lleó & Prinz 1996, McLeod et al 2001). Among the possible strategies are (i) production of a different consonant instead of the CC (sharing some of the features with one of the consonants in the CC or with no similarities at all), such as [daw] for *Frau* 'woman', or [dawn] for *Clown* 'clown' in German children (examples from Lleó & Prinz (1996: 38)), (ii) deletion of the whole cluster, as could be [aw] for *Frau* 'woman', and (iii) cluster reduction (CR) (Lleó & Prinz 1996). The most common strategy and longest lasting stage is CR, i.e., the omission of at least one of the consonants forming the CC (Smit 1993, Ohala 1999), such as [faw] or [raw] for *Frau* 'woman'. Children are not always consistent in the consonant the cluster is reduced to. Previous work on cluster reduction (CR) has led to a consensus in that the relative sonority of the consonants conforming the CC is key to determine the reduction pattern children exhibit. Accordingly, when there is a word-initial CC, only the least sonorous consonant prevails in early stages of syllabic onset acquisition (Goad & Rose 2004: 109). Sequences such as [tɾέn] *tren* 'train' are reduced to C1 [tέn], /t/ being less sonorous than /ɾ/. By contrast, sequences such as [stάr] *star* are reduced to C2 [tάr] since the sibilant /s/ is more sonorous than the stop /t/. The sonority explanation, however, has been found to be insufficient to account for all child productions documented. For instance, Lleó & Prinz (1996) report a preference for reduction to C1 in German children, whereas Spanish children tend to reduce to C2, producing sequences such as [glóβos] *globos* 'balloons' as [lóβos], even though the stop /g/ is less sonorous than the liquid /l/. Jongstra notices a similar problem in the CR patterns of Dutch, where /s/C, /kn, fl/ clusters are subject to variation, being reduced to C1 by some children and to C2 by others (2003: 9-10).

These findings have led to some discussion of additional features that explain the inconsistencies with the CR patterns observed. In the following sections I discuss two of the main proposals to account for the variation in CR variation, both within OT.

2.1 Pater & Barlow (2002)

Pater & Barlow argue that a number of markedness and faithfulness constraints independently motivated interact with consonant relative sonority, yielding all the possible results. According to them, CR is generally the result of a phonetically grounded fixed ranking of constraints, the order of which is correlated with their relative sonority. All else being equal, it is this ranking that picks the least sonorous element to be produced (2002: 533-4). The ranking is summarized in (4) (from Pater (1997)).

(4) *GLIDE-ONSET >> *LIQUID-ONSET >> *NASAL-ONSET >> *FRICATIVE-ONSET

However, as previously argued, some children do not follow the pattern above. To account for variation in CR consonant selection, the authors propose an alternative ranking based on two fundamental OT principles from Prince & Smolensky (1993), *factorial typology* (5), and *emergent constraint activity* (6) (adapted from Pater & Barlow (2002: 534))

(5) Factorial typology: All rankings of constraints should yield possible languages.

(6) Emergent constraint activity: Effects of violated constraints may be observed when higher ranked conflicting constraints are not at issue.

The principle of factorial typology establishes that all possible rankings of constraints should be attested in natural languages, thus avoiding overproduction of outcomes, while emergent constraint activity entails that even though a set of constraints such as the onset sonority constraints in (4) may be outranked, their pattern may emerge in the optimal candidate. Thus, in grammars such as *FRICATIVE >> *GLIDE-ONSET… when the input does not have a fricative, the effects of the onset sonority constraints emerge in the optimal candidate (e.g., selection of [buʃ] for *brush* instead of [ɾuʃ]).

Pater & Barlow (2002: 534) also note that children often utter fricatives as stops in early productions, in a pattern known as 'stopping' (e.g., [ti:] for [si:] *sea*). This phenomenon happens across the board (i.e., both in onset and coda position), and therefore *F-ONSET does not suffice as an explanation. To account for this pattern, the authors propose a context-free markedness constraint *FRICATIVE, shown in (7) (from Pater & Barlow (2002: 534)).

(7) *FRICATIVE: Segments may not be *[+CONT, -SON]

By ranking the sonority constraints higher than *FRICATIVE, CR to C1 is selected as the optimal candidate, whereas the opposite ranking entails CR to C2. This way, Pater & Barlow obtain both attested patterns for CR, shown in the tableau in (8) for *snow* (from Pater & Barlow (2002: 535)).

(8) a. *N-ONS >> *FRICATIVE

/snoʊ/	* N-ONS	*FRIC
noʊ	*!	
☞ soʊ		*

b. *FRICATIVE >> *N-ONS

/snoʊ/	* FRIC	*N-ONS
☞ noʊ		*
soʊ	*!	

(8a) shows the sonority pattern where the child selects the least sonorous element in the cluster. Conversely, (8b) exemplifies the pattern in which the child selects the candidate with the most sonorous consonant, because *FRICATIVE outranks the sonority constraints and selects the candidate than does not have the /s/.

To satisfy the factorial typology principle, Pater & Barlow contemplate the predicted rankings and test whether there is evidence for all of them. The factorial typology of *FRICATIVE and onset sonority constraints is given in (9) (from Table 1 in Pater & Barlow 2002: 540)).

(9) Factorial typology of *FRICATIVE and onset sonority constraints

		sw	sl	sn	st
a.	*G-ONS >> *L-ONS >> *N-ONS >> *F-ONS >> ***FRIC**	s	s	s	t
b.	*G-ONS >> *L-ONS >> *N-ONS >> ***FRIC** >> *F-ONS	s	s	s	t
c.	*G-ONS >> *L-ONS >> ***FRIC** >> *N-ONS >> *F-ONS	s	s	n	t
d.	*G-ONS >> ***FRIC** >> *L-ONS >> *N-ONS >> *F-ONS	s	l	n	t
e.	***FRIC** >> *G-ONS >> *L-ONS >> *N-ONS >> *F-ONS	w	l	n	t

All the rankings in (9) are attested but for (9d) (see §5 in Pater & Barlow (2002) for an account of the pattern predicted in (9d)). Additionally, the fixed ranking of onset sonority constraints yields the implicational prediction that if a segment of a given sonority is chosen instead of a fricative, then all segments of a lesser sonority will be chosen as well (Pater & Barlow 2002: 541). That is, if a word such as [snóʊ] *snow* is pronounced as [nóʊ], selecting the nasal, then [stóʊv] *stove* will be pronounced as [tóʊv], while [sɔ́rd] *sword* and [slóʊ] *slow* will be pronounced as [sórd] and [sóʊ], following the pattern in (9c). This also discards some patterns as impossible, for instance the production of [lóʊ] for *slow* and [sóʊ] for *snow*, which are in fact unattested[3]. Pater & Barlow found one last pattern that is left unpredicted by the typology above on a normally developing two-year-old (2002: 542). This last pattern consists of systematic reduction to C1, regardless of relative sonority of the CC. To account for this pattern, the authors propose the high ranking of a faithfulness constraint that demands the retention of word-initial consonants or anchoring (2002: 542).

All in all, Pater & Barlow's proposal provides an account of CR that goes beyond simple sonority patterns. However, the account at hand predicts the same realization of complex clusters such as /fl/ and /fɾ/, since both would belong to the same group *L-ONS, contrary to what the Dutch data collected by Jongstra (2003) shows (see §2.2). Moreover, the authors do not offer an account of how the child grammar reaches adult-like productions of whole clusters.

2.2 Jongstra (2003) based on Goad & Rose (2004)

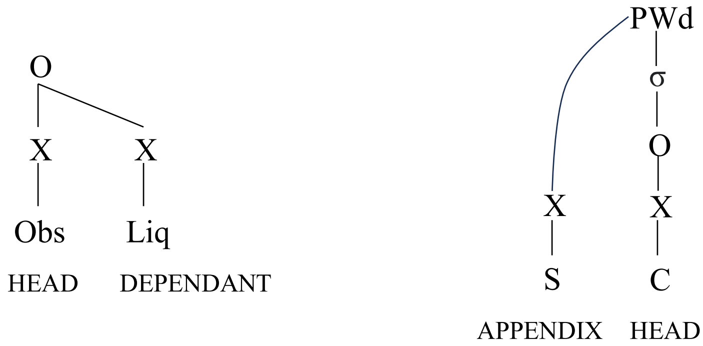
Goad & Rose (2004) claim that differences in the prosodic representation of the input is the cause of variation in word-initial /s/C clusters. In their proposal, they argue for a two-stage evolution of acquisition, distinguishing stage 1, where children only have simple onsets and select the head of the CC based on prosodic representation (i.e. the less sonorous segment is selected as the onset); and stage 2, where the child has a more complex structure and follows the head pattern. The difference in the output of stages 1 and 2 is only noticeable for /s/C clusters, where children in stage 1 select the obstruent

[3] Pater & Barlow do find evidence for two impossible patterns. These are accounted for with the inclusion of another constraint that is not discussed on this dissertation (see §5 in Pater & Barlow 2002).

and children in stage 2 select /s/. In this sense, Goad & Rose (2004:119) distinguish between two types of non-heads for both infant and adult grammars: dependants, which are a constituent of the onset (10a), and appendices, which are linked to a higher prosodic constituent (*PWd* below) (10b), (from (7) in Goad & Rose 2004).

(10) Unmarked syllabification options for left-edge clusters:

a. Branching onset b. Appendix+onset



In the head pattern, the child accesses the syllable-internal structure and always selects the head of the cluster in CR (2004: 110-3). To account for this, Goad & Rose propose a Max-Head(Onset) constraint, shown in (11) (from Jongstra (2003: 26)).

(11) Max-Head(Onset): every segment prosodified in the head of the onset in the input has a correspondent in the head of the output.

The faithfulness constraint Max-Head(Onset) penalizes the deletion of segments in the head of the syllabic onset. In addition, two assumptions need to be considered for this account: that branching onsets are left-headed and that the /s/ in adult grammars /s/C is a left-edge appendix (Jongstra 2003: 26). The latter is formalized through the markedness constraint *Appendix-left, shown in (12) (adapted from Goad & Rose (2004: 131)).

(12) *Appendix-left: A consonant at the left edge must be immediately dominated by Onset.

*Appendix-left is violated if the /s/ in the /s/C cluster is resyllabified as a coda, e.g., [əs.tɔ́p] *stop* in Catalan (c.f. §1.2). Goad & Rose propose that children share a single constraint ranking (13) that selects different optimal candidates depending on which segment is analyzed to be the head in the child's grammar.

(13) *Complex, *App-Left >> MaxHead >> Max (adapted from Jongstra 2003: 28)

Hence, Goad & Rose predict that the clusters /sw, sl, sm, sn/ will be variable depending on the syllabification pattern the child follows (i.e., stage 1 or 2), whereas other possible clusters will be stable (i.e., will be syllabified the same regardless of the syllabification pattern). Regarding the developmental path, the authors argue that children might go from stage 1 to stage 2 or skip stages, but never go backwards from stage 2 to stage 1 (Jongstra

2003: 107). Hence, not all children may exhibit both patterns of CR, but once the head pattern is acquired, the sonority pattern is discarded. Goad & Rose's proposal makes the following predictions for CR: children in stage 1 will select the least sonorous element in the CC, producing [sóʊ] for *snow*, regardless of syllable-internal structure. By contrast, children in stage 2 will select the head of the CC, producing [nóʊ] for *snow*. This leaves the variability in clusters such as /fɾ/ unaccounted for, since the head pattern makes the same predictions as the sonority pattern for this group. Goad & Rose's model also has an issue of over-prediction of patterns (Jongstra 2003: 109).

Jongstra observes that sequences such as /fl/ and /fɾ/ show a difference in stability in Dutch data regarding the pattern of CR (i.e., cluster reduction to C1 or to C2), /fl/ being more stable and /fɾ/ more variable (2003: 111). To overcome both Pater & Barlow (2002) and Goad & Rose (2004)'s incorrect predictions with respect to the Dutch data, Jongstra further develops Goad & Rose's model by adding Place of Articulation (PA) considerations alongside with sonority. Accordingly, stable CCs are those in which there is a large sonority distance and a different PA, such as /pl, sk/. Conversely, variable clusters are those in which the sonority is either similar or identical, such as /sx, fl/ (2003: 114). Sonority distance between C1 and C2 for Dutch word-initial CCs is represented in (14) (from (5.4) in Jongstra 2003). Sorority distance is calculated based on the sonority index that can be attributed to each sonority group, based on their rank in the sonority scale (Selkirk 1984). That is, considering that stops have a sonority index of 0, fricatives of 1, nasals of 2, laterals of 3, rhotics of 4, glides of 5 and vowels of 6 (based on Jongstra (2003: 114-5)), the sonority index is the result of the subtraction of a sound's index to the index of the other consonant in the cluster (e.g., the sonority distance between /p/ (0) and /f/ (1) is 1).

(14) distance	cluster groups	clusters
0	Fric + Fric	sx
1	(Fric + Stop), Fric + Nas	(sp, st, sk), sm, sn
2	Stop + Nas, Fric + Lat	kn, fl, fl, xl
3	Stop + Lat, Fric + Rhot	pl, bl, kl, fr, xr
4	Stop + Rhot, Fric + Glide	pr, br, tr, dr, kr, sw
5	Stop + Glide	tw

Consequently, the development from stage 1 (sonority pattern) to stage 2 (head pattern) in children involves both a development of the structure of the phonological input, as noted by Goad & Rose, and the beginning of making full use of the sonority scale, allowing for finer-tuned distinctions between rhotic and lateral liquids (Jongstra 2003: 114). Here, Jongstra argues that laterals are less sonorous than rhotics, drifting from the commonly accepted idea that liquids share the same sonority value (see Clements 1990). However, the distinction between laterals and rhotics in sonority has been previously defended in the literature (see Parker 2002, 2008, 2011, Baertsch 2012 and Proctor & Walker 2012). According to Jongstra, in stage 1 both /fl, fɾ/ seem to have a very close sonority, preventing the child from identifying the most sonorous segment. By contrast, when children reach the head pattern (stage 2), they notice the difference in sonority between the consonants in /fɾ/, while the difference in sonority between /fl/ remains too close for them to distinguish (2003: 115). Hence, children in stage 1 will show variability in the productions of /fl, fɾ/, whereas children in stage 2 will only exhibit variation in the production of /fl/, while /fɾ/ becomes stable at this stage.

Thus, in the head stage children evaluate the relationship between the consonants in the cluster. The higher sonority and PA difference, the better onset the cluster makes, and the easier it is to prosodify, leading to the realization of the head, commonly C1. As opposed, the closer the sonority, the less good an onset the cluster makes, and the more difficult to sillabify as a single onset (e.g., [pl], with a sonority distance of 3 makes a better onset than [sx], with a sonority distance of 0). In these cases, syllabification as appendix-head is more likely, analyzing C2 as the head of the cluster (2003: 118). Adult-like productions are argued to begin to take place in the head stage, when children start to prosodify both consonants. To account for the development from stage 1 to stage 2, Jongstra proposes that children take as point of departure /s/C clusters, which have low sonority distance and are right-headed. From these, children hypothesize that clusters with close sonority distances are always right-headed, instead of basing head selection on the least sonorous element in the cluster (2003: 117).

Jongstra (2003)'s proposal does a better job in predicting and accounting for variability in fricative-liquid clusters, which the previous accounts by Pater & Barlow (2002) and Goad & Rose (2004) did not consider. However, it has two implications that need some attention. On the one hand, the account proposed for the development from stage 1 to stage 2 depends on children's access to /s/C clusters to make generalizations about cluster headness. This leaves children acquiring languages where /s/C is not a possible word-initial onset (such as Catalan) out of the picture, which implies that for languages like Catalan we do not know how stage 2 is reached. On the other hand, Jongstra poses stage 2 as the gateway to adult-like productions. This contrasts with Goad & Rose's claim that stage 2 is not always a necessary step in phonological acquisition, and spawns further questions on how children acquiring languages such as Catalan might reach adult-like productions.

3 RESEARCH QUESTIONS

To recapitulate, CR is a commonly reported phenomenon when it comes to early productions of word-initial complex onsets (Smit 1993, Gierut 1999, Demuth & Kirk 2005), resulting in the realization of only one of the consonants in the cluster. Previous research on German and Spanish CR has found variation in the consonant the cluster is reduced to. While German children tend to reduce clusters to C1, Spanish children have a tendency towards reducing to C2 (Lleó & Prinz 1996). Other authors have found variation in the reduction pattern for some clusters in Dutch (Pater & Barlow 2002, Jongstra 2003, Goad & Rose 2004, Fikkert & Levelt 2008). Based on relative sonority, clusters such as /fl/ are argued to be less stable than clusters where the sonority distance between the consonants in the cluster is higher, such as /pɾ/.

Previous accounts for Catalan liquids distinguish trill rhotics as the least sonorous liquids establish no distinction between /l/ and /ɾ/ (Pons-Moll 2011). Under the assumptions of Pons-Moll, no difference in performance between C/ɾ/ and C/l/ clusters is expected. The first question this thesis aims to answer is whether there is a tendency towards reduction to one of the consonants and whether Catalan children will be consistent in their CR patterns. Our hypothesis is based on relative sonority and markedness accounts (Kiparsky 1979, Chin & Dinnsen 1992), arguing that the less sonorous element will be realized (i.e., C1 for Catalan CCs) for stop + liquid CCs. Regarding /f/ + liquid clusters, some variation is expected, since the relative sonority is lower (based on Jongstra 2003).

Another interesting aspect to assess is whether children are consistent in their strategies of onset production for a given cluster (i.e., always producing the whole cluster or consistently reducing the cluster, regardless of whether they reduce the CC to C1 or C2). In this sense, we expect that if a child is able to produce a cluster, the same production will be applied in all items within the same cluster. That is, a cluster such as [tɾ] might be pronounced as [tɾ], [t] or [ɾ], but the same pattern is expected to be followed for all words starting by the same cluster.

Finally, there is a lack of consensus in the available literature regarding at what age word-initial CC are mastered and what the different steps into adult-like productions are, reporting variation among both children and clusters (Smit 1993, McLeod et al 2001). Hence, this thesis aims to check if there are clusters that are more easily acquired (i.e., that show better performances at earlier ages) than others. According to Dissel (2007) and Lieven (2010), frequency of the target words may be expected to play a relevant role, expecting better performance in clusters that are more frequent in the child's environment. This contrasts with the predictions made in the second hypothesis, for Jongstra's hypothesis, within the generative grammar framework, predicts production based on relative sonority rather than frequency of the stimulus. The four main hypotheses considered, based on the assumptions of Jongstra (2003) and Dissel (2007), Lieven (2010), are:

HYPOTHESIS 1: Children reducing word-initial CC to a single consonant consistently select C1 for stop + liquid clusters and show some variation for /f/ + liquid clusters.

HYPOTHESIS 2: There is no difference in performance for C/l/ vs. C/ɾ/ clusters due to the similarity in sonority of the two consonants.

HYPOTHESIS 3: Children are within-cluster consistent in their word-initial CC production mechanism.

HYPOTHESIS 4: Frequency plays a role in word-initial CC acquisition, favoring those clusters that are more frequent in the target language.

4 EXPERIMENTAL STUDY

With views to evaluating the four hypotheses spelled out in §3, I designed an elicitation experiment to be run with Catalan-speaking children. The aim was to collect productions of word-initial complex onsets. Thus, a repetition task was designed, in which children were read a short story featuring a series of disjunctive questions that contraposed the target word and a distractor.

4.1 Stimuli

The experiment consisted of auditory stimuli provided by the experimenter, who read a short story which presented consecutive questions that opposed an item to a plausible alternative to get the relevant response form the participant, such as *avui en Pau i la Clara se'n van d'excursió. Com hi han arribat, en [distractor] o en [target]?* 'Today Pau and Clara are going on an excursion. Did they get there by [distractor] or by [target]?'. Questions were formulated so that the answer necessarily contained the target item, as exemplified in (15). The narration was accompanied by a set of colorful drawings that features a set of target items, as exemplified in Figure 1. These were presented sequentially in a set of six pages that were printed and coated. Due to the sequential nature of the story, the same order was presented to all children. See Appendix 1 for the complete set of images presented.

(15) *Avui en Pau i la Clara se'n van d'excursió. Com hi han arribat, en cotxe* [distractor] *o en tren* [target]*?*
'Today Pau and Clara are going on an excursion. Did they get there by car or by train?'

Figure 1. First page of the storybook

The set of target words consisted of 27 words, 21 of which were word-initial CCs, mainly of monosyllabic words, though some bisyllabic words were included. In addition, a set of 6 words with intervocalic liquids (i.e., [ɾ, r, l]) was included, which served as reference for the child's production of liquids. There were three items for each word-initial CC and two items for each intervocalic liquid. The words selected were easy to depict and familiar to toddlers of the target ages, although not all items were equally familiar to young children. In Table 1 I list the words used for each condition, followed by the English translation in italics. Number of items in parenthesis.

Table 1 Target words

Labial + Liquid	[pɾ] (n=3):	*prim* 'skinny'; *prat* 'field'; *primer* 'first'
	[pl] (n=3):	*plora* 'cries'; *plàtan* 'banana'; *plou* '(it) rains'
Dental + Liquid	[tɾ] (n=3):	*tren* 'train'; *tres* 'three'; *tractor* 'tractor'
Velar + Liquid	[kɾ] (n=3):	*crema* 'sunscreen'; *cranc* 'crab'; *crida* '(she) calls'
	[kl] (n=3):	*Clara; clau* 'key'; *closca* 'shell'
Fricative + Liquid	[fɾ] (n=3):	*fred* 'cold'; *front* 'forehead'; *fruita* 'fruit'
	[fl] (n=3):	*fletxa* 'arrow'; *flor* 'flower'; *flam* 'flan'
Intervocalic [ɾ]	V[ɾ]V (n=2):	*cara* 'face'; *pera* 'pear'
Intervocalic [r]	V[r]V (n=2):	*gorra* 'cap'; *sorra* 'sand'
Intervocalic [l]	V[l]V (n=2):	*pala* 'shovel'; *pilota* 'ball'

In parallel, we analyzed the frequency of the chosen words. On the one hand, we checked *Diccionari de Freqüènciess vol. 2* (*DF*, Rafel 1999) which gave us an idea of the frequency of the targeted words in non-literary texts. This was just an approximation, since it did not illustrate the frequency in which these words appear in child-directed speech. To offer a closer approximation, we looked for the target words in the transcriptions in the CHILDES database for Catalan. Table 2 lists the files included.

Table 2 CHILDES files included in the frequency analysis

name	files
Jordina	010719, 010723, 010803, 010827, 010911, 010925, 011024, 011106, 020301, 020709, 020918, 221016
Julia	010719, 010808, 010821, 010913, 010928, 011024, 011110, 011123, 020013, 020026, 020111, 020125, 020211, 020310, 020408, 020508, 020625
Eva	011005, 011110, 011117, 020100, 020100, 020109, 020114, 020127, 020302, 020306, 020404, 020410, 020410, 020511, 020624, 030010
Mireia	010600, 010625a, 010625b, 010629, 010704, 010912, 010925, 010926, 011003, 011009, 011100, 011104, 011105, 011110, 011112, 011115, 011123a, 011123b, 011125, 020003, 020004, 020009, 020102, 020104, 020114, 020129, 020201, 020203, 020214a, 02021b, 020216, 020220, 020221, 020300, 020302

Pascual	010804, 010809, 0100815, 010821, 020901, 020919, 011002, 011017, 011106, 011115, 011120, 02004, 020118, 020120, 020208, 020211, 020305, 0203021, 02030209, 020403, 020404,0204020, 0205020, 0206020, 020723, 020726, 020900, 021008, 021009, 021013, 021015, 021017, 021115, 021123, 030003, 030005, 030126, 030306
Alvar	010228, 010318, 020408, 020501, 020527, 010713, 010814, 011127, 020122, 020206, 020228, 020316, 020407, 030513, 020625, 020716, 020729, 020911, 021113, 030013, 030113
Gisela	010714, 010803, 010824, 010900, 011007, 011111, 020123, 020206, 020425, 020623, 020800, 020916, 021100, 030029, 030515, 030268, 031002, 031114
Guillem	010129, 020426, 020715, 010800, 010912, 010924, 011113, 020012, 020114, 020211, 020228, 020312, 020318, 020424, 020529, 020610, 020709, 020725, 020908, 021993, 021105, 021121, 021125, 030000, 030118, 030319, 030419, 020611, 030716, 031028, 031120
Laura	010720, 020907, 011022, 020205, 020213, 020411, 020508, 020625, 020720, 020830, 021117, 030002, 030321, 030513, 031000, 0310001, 031112

The frequency for most of the tokens turned out to be higher in the CHILDES scrutiny than in *DF*. Upon close inspection of the CHILDES results, most of the chosen words were among the most frequent words with word-initial consonant clusters. However, there were some words that had none or close to no representation in the database, such as *cranc* 'crab' or *prim* 'thin'. Ensuring familiarity to the target words in the study was impossible to control. Even so, the experiment consisted of a repetition task, thus familiarity to the target words was not deemed mandatory. See Appendix 2 for the frequencies for each of the target words in both the *DF* and the analyzed CHILDES database.

4.2 Participants

We tested 27 Catalan children (mean age: 2;10, range 2;2 to 3;3), including 17 boys and 10 girls, recruited from four different day-care centres from Sabadell (Barcelona). All children reportedly had a typical language development and were native Catalan speakers. The experiment was administered to three more participants (a total of 30), which were excluded due to language reasons (Participant 14, who is a Spanish speaker at home), undiagnosed language difficulties (Participant 16, who produces noises but does not talk at 3;1;20) and lack of attention (Participant 21 did not talk throughout the experiment).

Two age groups were further distinguished among the participants to determine whether there were developmental differences: the 2;8 age group (mean 2;8, range 2;2 to 2;11 (*participants =19)*) and the 3;1 age group (mean 3;1, range 3;0 to 3;3 *(participants =8)*).

4.3 Procedure

Toddlers were individually tested in a room at their day-care centre, an environment that was familiar to them. In some cases, a person from the day-care centre was present during the experiment. Participants were seated next to the experimenter in front of a table and the short story was placed before them in the form of a printed booklet. Children were told they would be read a short story the experimenter had drawn and needed to test if the pictures were clear enough. The sessions were audio recorded with the VoiceNotes App in an iPhone 11 placed in front of the child. Sessions were later transcribed by the experimenter. The analysis is based on the child's first response. Words that are not repeated but spontaneously produced are not distinguished in the analysis (e.g., the participant produced the target word before the question was asked). The mean duration of the whole story plus the interaction with the participant was 7'58''.

4.4 Coding

The answers were placed in a spreadsheet database. The independent variables considered are type of cluster evaluated (i.e., 7 word-initial complex onsets (CC) and 3 intervocalic liquids (VCV)), and items with each cluster, given in §4.1. For instance, the first cluster [tɾ] has three items 1) /tɾ/en *train*, 2) /tɾ/actor *tractor* and 3) /tɾ/es *three*. Derived words are included in each subtype category (i.e., 'trenet' *little train* is counted as subtype 1). Responses were coded according to type of phonological process, given in Table 3.

The analysis was restricted to the word-initial consonant cluster. For instance, productions with a vowel shift (such as [plítʃə] for [flétʃə] *fletxa* 'arrow') were counted considering the production of the word-initial cluster alone (in this case, ≠C1).

Table 3 Codes used to indicate different mechanisms for cluster production

code	**process**
NR	no response/distractor/other
TC	C1C2 realization
≠C1	C1C2 realization where C1 is not the target consonant
≠C2	C1C2 realization where C2 is not the target consonant
CR	cluster reduction (always reduced to C1)
CR ≠C1	cluster reduction to C1 where C1 is not the target consonant
CR:	cluster reduction where V is lengthened
ØC	consonant deletion (both C1 and C2, or C in VCV items)
≠C	different consonant in VCV items

NR is used to encode all the answers that did not match the target item, including the instances where the child produced the distractor, chose another word, or uttered no answer. Productions that were not clear enough to make an accurate transcription were also labeled as NR. *TC* (i.e., *target cluster*) indicates all the cases where the child produced both consonants in the cluster (adult-like realization). *≠C1* encodes the cases where the child produced a cluster where C1 is different from the one on the target cluster, such as [pɾ] for [fɾ] in *fred* 'cold'. *≠C2* labels the realizations where the child produced a cluster where C2 was different from the one on the target cluster, such as [pl] for [pɾ] in *prat* 'field'. *CR* refers to productions of only one consonant in the cluster. Participants consistently reduced the cluster to C1, and therefore no further distinctions are made. *CR≠C1* encodes instances where the child reduced the cluster to C1 but uttered a different consonant, such as [p] for [fɾ] in *fruita* 'fruit'. *CR:* labels realizations of cluster reduction where the following vowel was lengthened, such as [pá:] for [pɾát] *prat* 'field'. ØC refers to the cases where no consonant was uttered. These occur mainly in VCV contexts (e.g., [piɔ́tə] for [pilɔ́tə] *pilota* 'ball') but have an instance in a word-initial complex cluster context ([ám] for [flám] *flam* 'flan'). *≠C* encodes the cases in VCV items where the consonant was replaced with a different one, such as [l] for [r] in *sorra* 'sand'. See Appendix 4 for the whole data in a spreadsheet format.

5 RESULTS

A total of 729 words were collected. Following the coding described in §4.4, there are two ways to determine whether a participant produced a correct answer. Correct realizations include those in which the child produces two consonants in the syllabic onset. Following Jongstra (2003), the present study follows a strict analysis of correct realizations (*strict TC*), which contemplate exclusively productions where both consonants realized are identical to the adult-like cluster (TC), excluding productions such as [pɾɛ́t] for [fɾɛ́t] in *fred* 'cold'. By contrast, the liberal analysis of correct realizations (*liberal TC*) includes productions where one of the consonants is not the target consonant (i.e., including mechanisms ≠C1 and ≠C2 respectively). As we will see, the results do not always vary depending on the type of analysis (see §5.1). Since the strict TC analysis allows for a more accurate discussion, I follow it for the discussion below. CR can also be analyzed in two different ways. The strict CR analysis (*strict CR*) only considers as CR the cases where the participant reduces the cluster to one of the target consonants, excluding productions such as [tɛ́t] and [f:ɛ́t] for [fɾɛ́t] in *fred* 'cold'[4].

The figures that follow display the results from the experiment described in §4. Firstly, I present the overall results for the participants, distinguishing between the results for word-initial complex clusters and the results for intervocalic singletons (§5.1). Then, I move to presenting the results for the participants distinguishing two age groups (§5.2).

[4] The liberal CR analysis (*liberal CR*) includes instances where the participant produces a different consonant from C1(when changing C1, participants maintained some of the target consonant's features (i.e., voice, sonority, Manner of Articulation (MA), or PA). See Appendix 4 for the table with the complete results and consonant shift) (CR≠C1) or lengthens the consonant (CR:). In this case, the increase in performance is minimum when considering CR:, but there is a significant difference between strict and liberal CR when considering CR≠C1(see §5.1). For this reason, I maintain the distinction in the following analysis.

Adult participants produced the target clusters (TC mechanism) for all conditions, and therefore is not discussed any further.

5.1 Results for all participants

The experiment features a set of 6 items that aimed to check whether the participant had acquired liquids as a singleton. The overall results for VCV liquid performance are included in Table 4. Catalan word-initial complex clusters only feature [ɾ, l], but [r] was included in the study for completeness since it is in contrasting distribution with [ɾ] in intervocalic contexts. However, (under)performance of [r] is not of great concern for the present study.

Table 4 Frequency of mechanisms and NR for VCV
Percentages are calculated in relation to the number of singletons produced per condition (n=54). *T* here and below refers to the realization of the target singleton.

	NR		T		ØC		≠C	
	n	%	n	%	n	%	n	%
V[ɾ]V	6	11.11	31	57.41	1	1.85	17	31.48
V[r]V	12	22.22	9	16.67	0	0.00	32	59.26
V[l]V	4	7.41	47	87.04	3	5.56	0	0.00

The target production of both [ɾ, l] is above 50%, indicating that most participants had acquired both singletons at the time of the experiment. By contrast, the target production of [r] is below the 50% (i.e., a 16.67%). Most participants produced a different consonant (namely, either [ɾ], [l] or an approximant), indicating that they had not mastered the trill rhotic by the time of the experiment.

Table 4.1 features the realization of each VCV item per participant. As shown, most participants have trouble producing intervocalic [r] (22 out of 27 produced a different consonant for at least one of the items). However, the performance for [l] and [ɾ] is better ([l] being the most well produced, with only two participants omitting the consonant, and [ɾ] falling in the middle, with 11 participants producing the target consonant in both items, 4 producing a different consonant and 7 producing both a target singleton and a different consonant).

Table 4.1 Mechanisms and NR for VCV per participant
(*grey*=NR; *blue*=T; *light orange*=≠C; *orange*=ØC).

	V[ɾ]V		V[r]V		V[l]V	
	pera	cara	gorra	sorra	pilota	pala
22	T	T	≠C	≠C	T	T
24	≠C	T	≠C	≠C	T	T
4	≠C	T	≠C	≠C	T	T
1	T	≠C	T	T	T	T
30	T	T	≠C	T	T	T
20	T	T	≠C	≠C	T	T
5	≠C	T	T	T	T	T
26	T	NR	≠C	NR	ØC	ØC
17	≠C	≠C	≠C	≠C	T	T
18	≠C	T	≠C	≠C	T	T
23	T	T	≠C	≠C	T	NR
8	≠C	≠C	≠C	NR	T	T
29	T	T	≠C	≠C	NR	T
28	T	T	NR	T	T	T
13	≠C	≠C	NR	NR	T	T
19	T	T	≠C	NR	T	T
3	NR	NR	NR	≠C	T	NR
6	T	T	T	NR	T	T
9	T	NR	≠C	T	T	T
15	≠C	≠C	ØC	≠C	T	T
25	T	≠C	T	≠C	T	T
27	≠C	NR	≠C	≠C	T	T
12	T	T	NR	≠C	T	T
7	T	T	≠C	NR	T	T
11	T	≠C	≠C	NR	T	T
10	≠C	NR	≠C	NR	ØC	NR
2	T	T	≠C	≠C	T	T

Starting with the results for word-initial CCs, Figure 2 shows the frequency of each mechanism and NR for each of the CC included in the study (see Appendix 4.1 for the data in a spreadsheet table format). As argued above, the results in this section are based on the strict analysis.

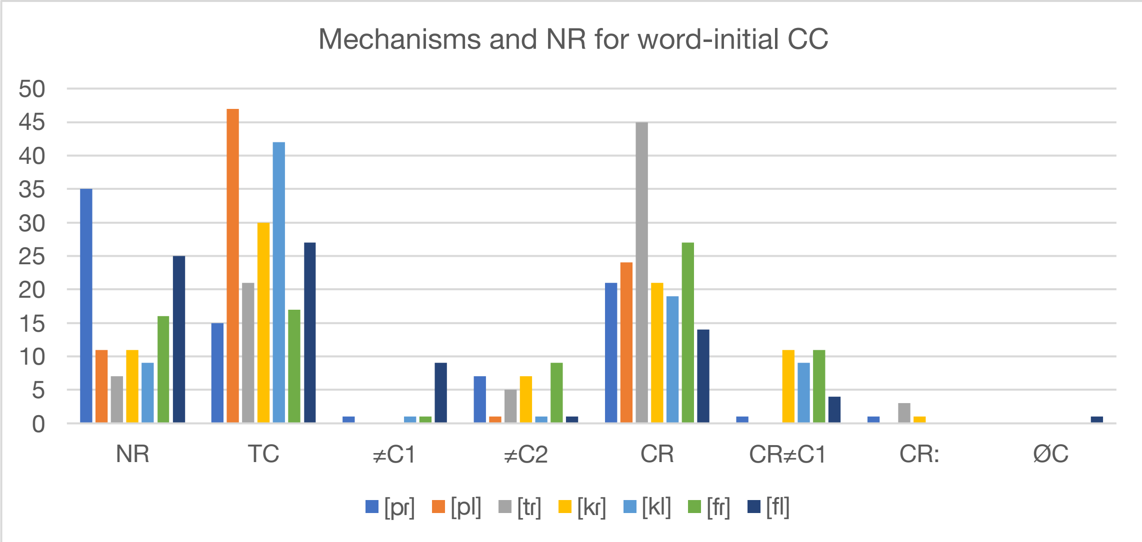


Figure 2. Mechanisms and NR for word-initial CC

Figure 2 shows that there is no clear tendency towards any mechanism that applies across the board, indicating that participants do not apply a single mechanism to all clusters. Contrarily, each CC seems to have a preferred production pattern. For instance, there is a tendency to reduce [tɾ] to a single consonant. The cluster was produced as CR in 55.56% of the utterances (n=45), whereas it was produced as TC in 25.93% of the utterances (n=21). By contrast, clusters such as [pl] have the opposite effect, where TC is preferred (58.02%, n=47) to CR (29.63%, n=24)[5].

Figures 2.1-2.7 display a more detailed approach to the data in Figure 2, where the frequency of each mechanism and NR is shown for each of the three items per condition (see Appendix 4.2 for the data in a spreadsheets table format).

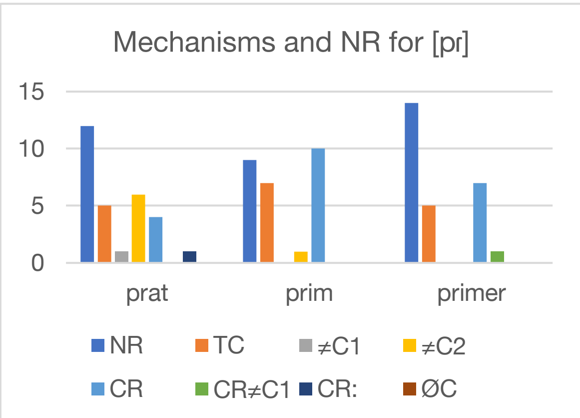


Figure 2.1. Mechanisms and NR for [pɾ]

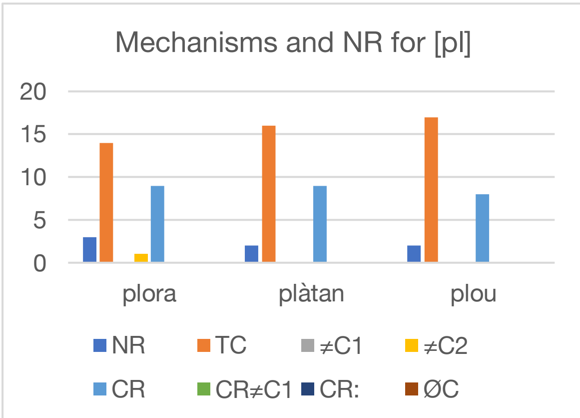


Figure 2.2. Mechanisms and NR for [pl]

[5] Some of the clusters present an increase of the performance in the liberal analysis. For instance, [pɾ] shows 18.52% (n=15) of correct realizations in the strict TC analysis, whereas in the liberal analysis the performance rises to a 28.40% (n=23). On the other hand, clusters such as [fɾ] show a difference in the strict and liberal CR analysis, where the strict analysis shows a performance of a 33.33% (n=27) of CR and 13.58% (n=11) of CR≠C1, versus the liberal analysis, which shows a 46.91% (n=38) of CR.

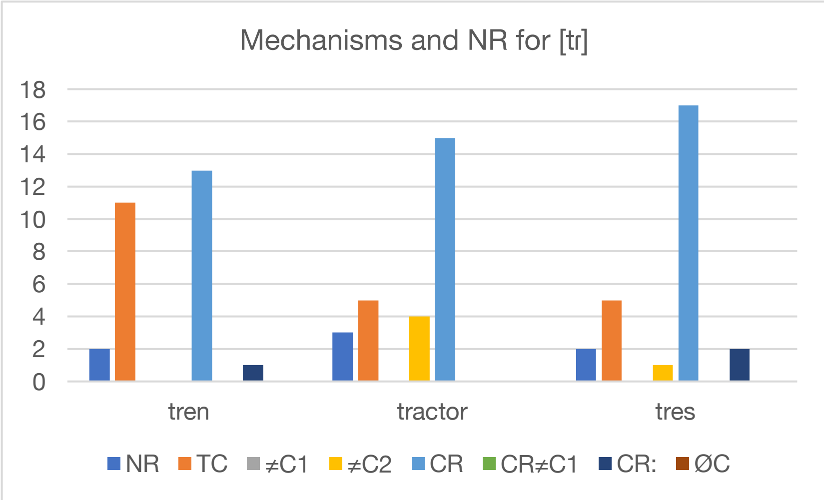


Figure 2.3. Mechanisms and NR for [tɾ]

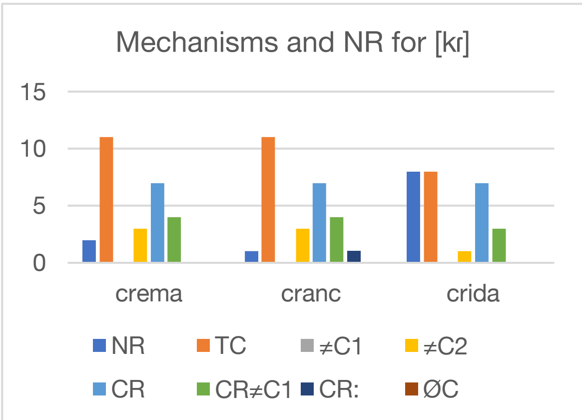


Figure 2.4. Mechanisms and NR for [kɾ]

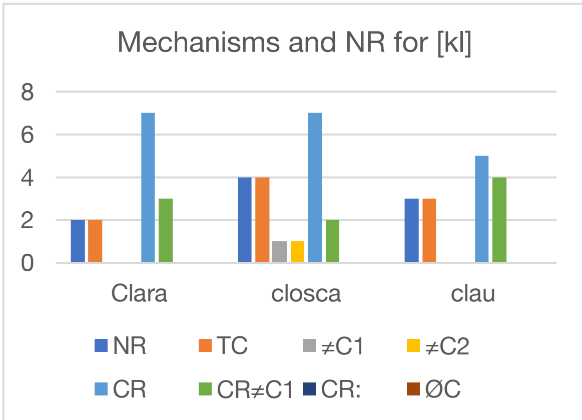


Figure 2.5. Mechanisms and NR for [kl]

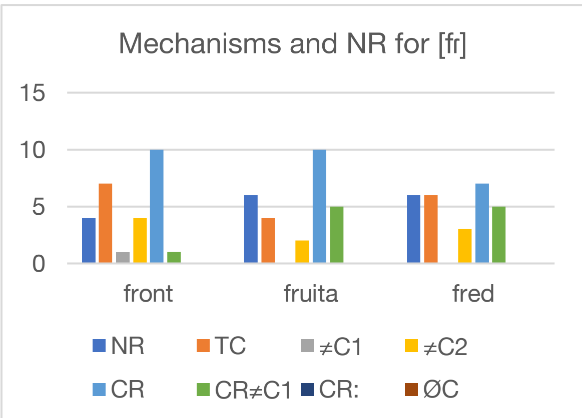


Figure 2.6. Mechanisms and NR for [fɾ]

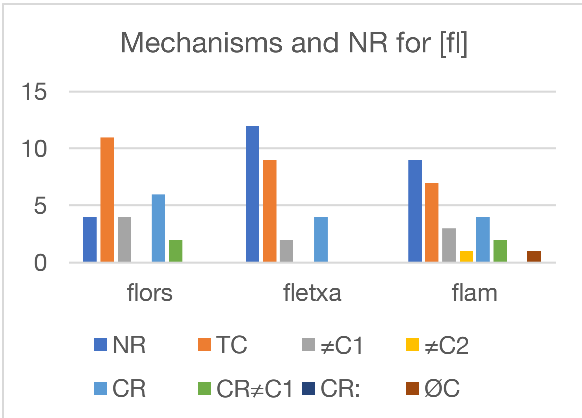


Figure 2.7. Mechanisms and NR for [fl]

Figures 2.1-2.7 show that items belonging to the same condition present different results. E.g., for *tren* 'train' in Figure 2.3 there are 11 correct productions of the whole cluster, and 13 CR productions. Even though the preferred production is CR, the preference is not as strong as for the words *tractor* 'tractor' and *tres* 'three', where the TC production is only featured 5 times and CR productions are featured 15 and 17 times, respectively. Moreover, Figures 2.1-2.7 highlight that some words were more difficult for the participants to imitate, such as *prat* 'field', *primer* 'first' (Fig. 2.1), or *fletxa* 'arrow' (Fig. 2.7), where the NR score is between 12 and 14. In this line, [k] and [f] seem to be the consonants that are most difficult to produce, since they are the consonants that have the highest rates of CR ≠C1 (e.g., [táðə] for 'Clara' *Clara*) and [f] of ≠C1 (e.g., [plós] for 'flors' *flowers*).

Figure 3 displays the frequency in which each child used each mechanism and NR (see Appendix 5 for the data in a spreadsheets table format). Participants are ordered by age, Participant 22 (2;2;1) being the youngest and Participant 2 being the oldest (3;3;18)

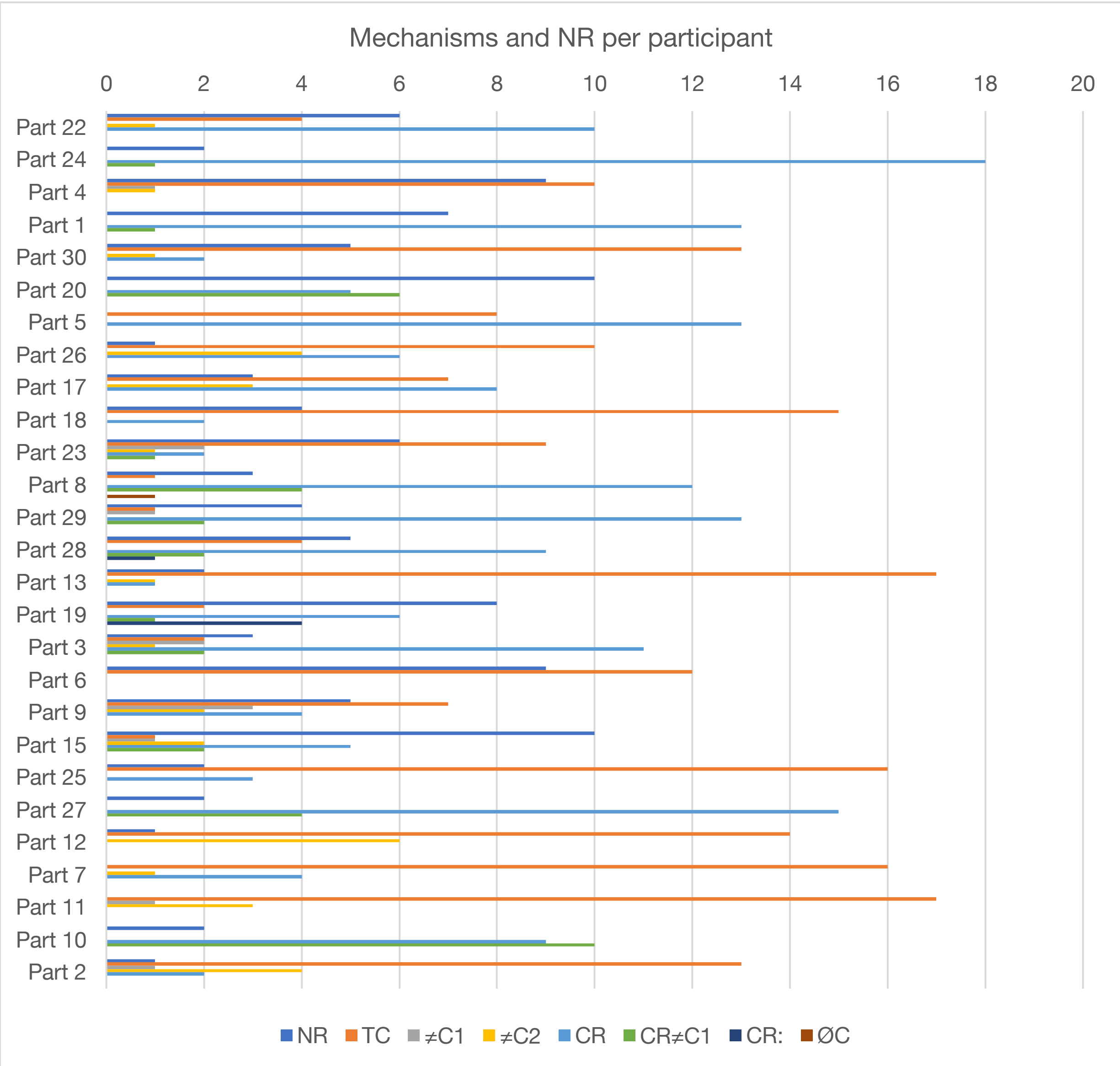


Figure 3. Mechanisms and NR per participant

Figure 3 shows that some participants have a preference for either TC or CR. E.g., Participant 24 produced an 85.71% of the clusters as CR (n=18) and no TC cluster. Participant 13 produced an 80.95% of the clusters as TC (n=17), and only a 4.76% as CR (n=1). However, other participants produced clusters following TC and CR indistinctively. E.g., Participant 17 produced a 33.33% of the clusters as TC (n=7) and a 38.10% as CR (n=8). Participants show different levels of development. For instance, Participant 13 (2;10;21) produces most clusters as TC (n=17, an 80.95%), whereas the older Participant 27 (3;0;13) produces most clusters as CR (n=15, an 71.43%). This, however, only means that Participant 13 is more advanced in word-initial complex onset production. The issue is recovered in §5 for the discussion.

The last condition relevant for the discussion of the results is the frequency of CR to C1 and C2. Regarding this condition, no participant produced a CR to C2. Hence, CR were consistently to C1 (a 100%, n=171).

5.2 Results for all participants distinguishing two age groups

For this part of the analysis two age groups are distinguished, participants younger than three years old (the 2;8 age group, based on mean age of the group) and those who were older than three (the 3;1 age group, idem). Starting with word-initial CC, Figure 4 shows the frequency of each mechanism and NR for each of the clusters included in the study. Each age group is identified by the mean age (see Appendix 6.2 for the data in a spreadsheets table format and Appendix 6.3 for production of each mechanism for each of the three items per condition).

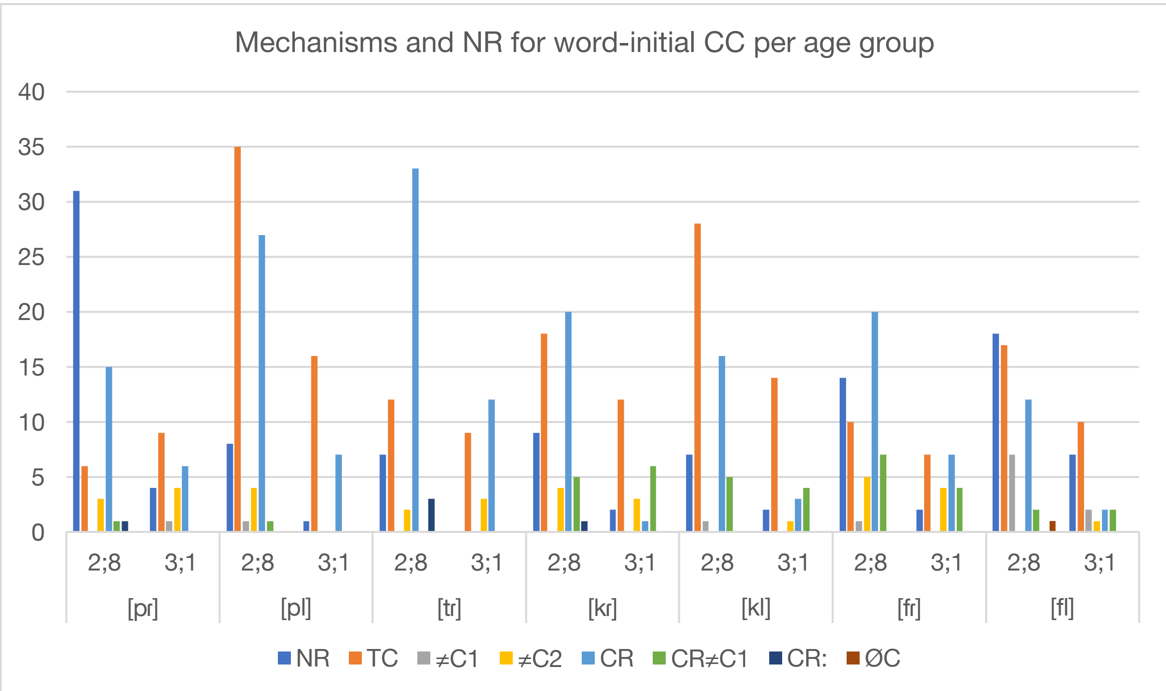


Figure 4. Mechanisms and NR for word-initial CC per age group

There seems to be a slight difference between the mechanism preferred by each age group. The cluster that shows the greatest difference in performance is [pɾ], where the 3;1 age group produces the TC a 37.50% (n= 9) of the utterances, whereas the 2;8 group only produces TC a 10.53% (n=6). However, the proportion of CR in the cluster is very close (26.32% (n=15) in the 2;8 age group and 25% (n=6) in the 3;1 age group), indicating that the difference in TC performance is due to the high rate of NR in the 2;8 age group for the cluster (a 54.39%, n=31). Another cluster that presents a relevant difference in production is [kɾ]. When comparing TC for both age groups, the 3;1 age group produces TC a 50% (n=12) of the utterances, which contrasts with the 2;8 age group's production of TC at a rate of 31.58% (n=18). These results align with the CR results for the same cluster, where the 3;1 age group only reduces the cluster a 4.17% (n=1) of the utterances, while the 2;8 age group does it a 35.09% (n=20). For clusters [tɾ, fɾ, fl] there seems to be a similar tendency, where age 3;1 performs slightly better, producing between 12-27% more TC than the 2;8 age group. For clusters [tɾ, fɾ] the CR production shows not much of a difference among the two age groups. For instance, both age groups show a preference for CR in the [tɾ] condition, the 2;8 age group producing a 57.89% of CR (n=33) versus a 21,05% of TC (n=12), and the 3;1 age group similarly showing a preference towards CR (n=12, a 50%) and a slightly higher tendency towards TC productions (n=9, a 37.50%). For [fɾ], the 3;1 age group does not show a preference towards either process (n=7, a 29,17% in both TC and CR). For [fl], the 3;1 age group performs a 11.85% more TC and less CR, showing a slightly better performance than the 2;8 age group. For the clusters [pl, kl], the proportion of TC answers among each age group is very similar, producing TC clusters around 50% of the time.

6 DISCUSSION

The first striking aspect that results from the experiment is that participants consistently reduced word-initial complex onsets to C1. Among the 171 productions of CR, none was reduced to C2. In this sense, Catalan parallels with German, as opposed to languages such as Spanish, which tend to reduce clusters to C2 (Lleó & Prinz 1996). This result contrasts with Jongstra (2003)'s finding that some clusters are variable regarding the reduction pattern. A possible explanation for the consistent cluster reduction to C1 can be that the participants of the study had not yet acquired liquid consonants, since the lack of liquids in their consonant inventory could entail a production of the stop in the cluster alone. However, the results for the VCV condition indicate otherwise. Most participants produce [ɾ, l] at least once in the experiment. Starting with [l], only participants 1 and 19 fail to produce it in intervocalic position. However, child 19 produces [l] as part of a cluster in 'plou' *(it) rains* and 'Clara' *Clara*, indicating that the lateral consonant has not been acquired. Regarding [ɾ], participants 5, 10 and 20 do not produce the tap rhotic in any of the conditions, indicating that their pattern of CR can be due to their not having acquired [ɾ] by the time of the experiment. In addition, participants 1 and 27, do not produce the rhotic in the V[ɾ]V condition but do produce it in the V[r]V condition. However, the participants that did produce one of the liquids in the VCV condition (i.e., 19 for [ɾ] and 5, 10, 20, 27 for [l]) still consistently reduce CCs to C1, indicating that CR to C1 is not strictly related to the acquisition of the liquid, but rather a more general bias. The first conclusion from the present study is that Catalan word-initial CCs are consistently reduced to C1. This agrees partly with Hypothesis 1, repeated here for convenience.

HYPOTHESIS 1: Children reducing word-initial CC to a single consonant consistently select C1 for stop + liquid clusters and show some variation for /f/ + liquid clusters.

CR to C1 was correctly predicted for stop + liquid clusters, but the data from the experiment debunks the claim that /f/ + liquid clusters would show variability. An explanation for the consistent CR to C1 can be found in the reported preference towards a sharp rise in sonority for onsets (Clements 1990, Bonet & Mascaró 1997). Thus, onsets such as [t]en for *tren* 'train' are preferred to onsets such as [ɾ]en, since [t] is less sonorous than [ɾ] and therefore the rise in sonority towards the vowel (i.e., the nucleus) is stronger. This explanation, however, requires a different account that explains why children acquiring languages such as Spanish prefer CR to C2 in words where C2 is less sonorous than C1 (see §2).

When taking a close look at the production of C/ɾ/ vs. C/l/ clusters, each pair needs to be discussed separately. Starting with [pɾ] – [pl], there is a prominent issue with the experiment's design for the [pɾ] condition, since there is a high rate of NR (43.21%, n=35), indicating that the items selected for the experiment seem to be unfamiliar to the 2;8 age group. However, the results for CR are similar between the two clusters, 25.93% (n=21) for [pɾ] and 29.63% (n=24) for [pl]. For the [kɾ] – [kl] pair, the results seem to be better for the [kl] cluster, producing TC 51.85% (n=42) and CR 23.46% (n=19) of the times. By contrast, the [kɾ] group has TC production a 37.04% (n=30) and CR a 25.93% (n=21). The difference in TC production between the two groups is partially explained by the tendency towards producing [kɾ] as [kl] (≠C2 mechanism), which occurs in an additional 4.94% (n=4) of productions. This seems to reinforce the idea that [kl] is an easier CC group to produce than [kɾ]. The third pair that can be compared is [fɾ] – [fl], where the later displays a high rate of NR (30.86%, n=25). Even so, the [fl] cluster has better results than [fɾ], the former having a TC production 33.33% (n=27) and CR 17.28% (n=14) of the times, and the latter having TC 20.99% (n=17) and CR 33.33% (n=27) of the times. In sight of this, it appears that C/l/ clusters are more easily produced by Catalan children, whereas C/ɾ/ clusters have a slight disadvantage in production. Following previous accounts of word-initial CC acquisition, this difference can be explained by the relative sonority of stop, [f] + [l] clusters compared to stop, [f] + [ɾ] clusters. In this sense, it seems that the difference in sonority between [ɾ, l] in Catalan is relevant for word-initial CC acquisition, and that /ɾ/ is more sonorous than /l/. This goes along with the findings by Jongstra (2003) and has also been previously defended by Parker (2002, 2008, 2011), Baertsch (2012) and Proctor & Walker (2012). These results contradict the predictions in Hypothesis 2, repeated below for convenience.

HYPOTHESIS 2: There is no difference in performance for C/l/ vs. C/ɾ/ clusters due to the similarity in sonority of the two consonants.

To further fine-tune this notion, a hierarchy of ease of production, that is, adult-like production (TC), can be drawn, based on the data from Figure 2 (16). A second hierarchy can be drawn for the same data, establishing the CCs that are most prone to child-like productions (i.e., non-TC productions, including NR, CR, ≠C1, ≠C2, CR≠C1, CR: and ØC), ordered in (17) from higher to lower rate of child-like productions.

(16) Hierarchy of adult-like production per cluster
[pl] > [kl] > [kɾ] > [fl] > [tɾ] > [fɾ] > [pɾ]

(17) Hierarchy of child-like production per cluster
[tɾ] > [pl] > [fɾ] > [fl] > [kɾ] > [kl] > [pɾ]

The position of [pɾ] in (16) is unexpectedly low, given the high difference in relative sonority between the two consonants (sonority distance = 4). It can be attributed to the high rate of NR answers in the experiment for this cluster. For the other clusters, it seems that relative sonority does play a role, [pl, kl, kɾ] being ranked above [fl, fɾ]. The realization of [tɾ] also shows an unexpectedly low position, given the high distance between the two consonants in the cluster (sonority distance = 4). (17) seems to mirror the hierarchy for ease of production, which reinforces the results of (16) for most clusters. Only [pl, pɾ] show unexpected positions in the hierarchy. This can be argued to support the idea that the low ranking of [pɾ] for the adult-like production is influenced by its high rate of NR answers in the study, since it shows a very similar rate of child-like productions to the clusters that are most easily produced in the adult-like hierarchy[6]. Similarly, [pl] features a high position in both hierarchies, yielding the results for the cluster less conclusive.

When distinguishing the two age groups, results seem to be clearer. The hierarchies of adult-like (18) and child-like (19) productions that can be drawn from each age group show slight dissonances (drawn from the data in Figure 4).

(18) Hierarchy of adult-like production per cluster and age group
2;8 [pl] > [kl] > [kɾ] > [fl] > [tɾ] > [fɾ] > [pɾ]
3;1 [pl] > [kl] > [kɾ] > [fl] > [tɾ], [pɾ] > [fɾ]

[6] The hierarchy in (17) includes the rate of no responses as child-like productions. Upon taking a look at child-like productions excluding NR (i.e., CR, ≠C1, ≠C2, CR≠C1, CR: and ØC), the results vary. Cf. the hierarchy in (17) with the one in (i), where the cluster [pɾ] has a higher position and [pl, fl] are ranked lower when excluding NR.

(i) Hierarchy of child-like production per cluster excluding NR
[tɾ] > [fɾ] > [kɾ] > [pɾ] > [kl] > [fl] > [pl]

(i) reinforces the distinction between C[ɾ] clusters, which display a higher frequency of child-like answers, and C[l] clusters, which show less child-like answers.

(19) Hierarchy of child-like production per cluster and age group

2;8 [pɾ] > [fɾ] > [tɾ] > [fl] > [kɾ] > [pl] > [kl]

3;1 [fɾ] > [pl], [tɾ] > [fl] > [kɾ] > [pɾ] > [kl]

The hierarchies for ease of production in (18) show little difference to the overall hierarchy shown in (16). The 3;1 age group does show a better performance for the [pɾ] cluster, which can be attributed to its low rate of NR. In this sense, the results for the 3;1 are more reliable for this cluster. Regarding the hierarchies for child-like productions in (19), the results for the 2;8 age group mirror those for the adult-like productions, with only a slight change between [pl] and [kl], [kl] having both less child- and adult-like productions. For the 3;1 age group, the hierarchy for child-like productions also mirrors the hierarchy for ease of articulation, only showing a contrast between the ranking of [pl], ranked high in both hierarchies, and [pɾ], ranked low in both hierarchies[7]. In view of this inconsistency, the results for the 3;1 age group seem to be less reliable and to have affected the outcome of the general hierarchies in (16, 17). By contrast, if we consider the larger 2;8 age group, the hierarchies seem to concord, establishing [pl] as the easiest cluster to produce and [pɾ] as the most difficult. The results for the child-like hierarchies confirm [tɾ, fɾ] as harder to acquire, while agreeing that [pl, kl] are acquired early on.

A limitation of the present study is that the two age groups show a small difference in mean age. Further research on the field could benefit from choosing a wider range of participants that allows for a more differentiated comparison.

The third hypothesis, repeated here for convenience, was that participants would be consistent with their CC production mechanisms (i.e., they would produce all items in the same condition with the same mechanism). From the 27 participants in the study, 13 children (48.15%) used different mechanisms for the different items in the same condition, as collected in Table 5 (adapted from Appendix 3.2).

HYPOTHESIS 3: Children are within-cluster consistent in their word-initial CC production mechanism.

[7] The hierarchies in (19) include the rate of NR as child-like productions. The alternative approach, excluding NR from child-like productions, shows different results. Cf. the hierarchies in (19) with the ones in (ii).

(ii) Hierarchy of child-like production per cluster per age group excluding NR

2;8 [tɾ] > [fɾ] > [kɾ] > [pl] > [kl] > [fl] > [pɾ]

3;1 [tɾ], [fɾ] > [pɾ] > [kɾ] > [kl] > [pl] > [fl]

The difference in the position of [pɾ] in (19) and (ii) for the 2;8 age group (from first position in (19) to last in (ii)), indicates that the results for this cluster are influenced by its high rate of NR. On the other hand, the results for the 3;1 age group show significant differences for the clusters [pɾ, pl, fl], resulting in a hierarchy that is more faithful in mirroring the hierarchy for adult-like productions in (18). All in all, both hierarchies in (ii) establish the same pattern where C[ɾ] clusters have more child-like productions than C[l] clusters, except for the case of [pɾ] in the 2;8 age group.

Table 5. Participants that display different mechanisms per cluster
(*grey*=NR; *blue*=TC; *light orange*=≠C; *orange*=ØC).

participant	**22**	**17**	**23**	**29**	**28**	**13**	**19**	**3**	**9**	**15**	**25**	**7**	**2**
prat	TC											≠C2	≠C2
prim	CR											TC	CR
primer	NR											CR	TC
plora	CR	CR		TC	CR		CR	CR		NR			
plàtan	CR	TC		CR	CR		NR	TC		TC			
plou	TC	CR		CR	TC		TC	NR		CR			
tren			TC							CR	TC	TC	TC
tractor			NR							≠C2	TC	CR	CR
tres			CR							CR	CR	CR	TC
crema		≠C2	TC										
cranc		TC	TC										
crida		CR	CR										
Clara		TC			TC	NR	TC	CR					
closca		TC			CR	CR	CR	≠C1					
clau		CR			TC	TC	CR≠C1	TC					
front									≠C1			TC	
fruita									CR			CR	
fred									≠C2			TC	
flors													
fletxa													
flam													

As seen in Table 5, some CCs (i.e., consonant clusters) show within-child within-cluster variation, where a participant produces TC and CR for the different items in the same cluster. For instance, participant 17 produces [tέn] for 'tren' *train* (CR), [tɾəktó] for 'tractor' *tractor* (TC) and [tέs] for 'tres' *three* (TC). The clusters that show the highest within-child within-cluster variation are [pl, kl, tɾ] followed by [pɾ] and [fɾ, kɾ]. The only cluster for which this phenomenon was not observed is [fl]. This contrasts with the results per cluster, since the most highly ranked clusters are also the ones that present most within-child within-cluster variation. Even though age does not seem to play a role in variability, younger children are more stable regarding their productions, while it increases in older participants. This can be interpreted as low stages of CC production, where the children that have started producing word-initial CCs are not yet too confident in their production, going back to CR for some items. However, the overall production of TC (n=199 for strict TC and n=242 for liberal TC) productions is higher than for CR (n=173 for strict CR and n=219 for liberal CR), where the 2;8 age group show a tendency towards CR (n=135), rather than TC (n=126).

The final hypothesis for this thesis, repeated below for convenience, states that clusters that are more frequent in the child's environment will be more easily acquired.

This has not turned out to be true for the results of our study. The hierarchies of ease of production and frequency are compared in (19) for clusters and in (20) for each item, based on the frequency in the CHILDES database (see Appendix 2).

HYPOTHESIS 4: Frequency plays a role in word-initial CC acquisition, favoring those clusters that are more frequent in the target language.

(20) a. ease of CC production [pl] > [kl] > [kɾ] > [fl] > [tɾ] > [fɾ] > [pɾ]

b. CC frequency [pɾ] > [tɾ] > [kɾ] > [pl] > [kl] > [fɾ] > [fl]

(21) a. ease of item production
plou > plàtan > plora > tren, crema, cranc, flors > fletxa > crida > prim, front, flam > fred > primer, prat, tractor, tres > closca, fruita > clau > Clara

b. item frequency
plora > tres > primer > crida > crema > plàtan > tractor > tren > Clara > fred > plou > flor > flam > fruita > clau > front > prat, closca > fletxa > cranc

Opposed to what was expected under Dissel (2007) and Lieven (2010)'s hypothesis, it seems that there is an almost reverse relation between frequency and ease of production. In sight of this, relative sonority has a great effect in word-initial CC production, whereas frequency does not play any role.

Even though establishing the age in which Catalan children have mastered word-initial CCs was not a goal for this dissertation, a small paragraph can be dedicated to this end. From the 27 participants in the experiment, no child produced all items in an adult-like way in the strict TC sense. Participants 4 (age 2;6;22), 11 (age 3;2;6) and 12 (age 3;1;16) produced all the target clusters in an adult-like fashion if we take the liberal TC analysis. However, only participant 11 produced all items in the study, the other two leaving some items as NR. Seemingly, only participants 1 (age 2;6;24), 24 (age 2;2;28) and 27 (age 3;0;25) produced all items as CR, even though they all left some items as NR. In this sense, the results of the experiment show that word-initial CC production starts before 2;2 years (the age of the youngest participant) and its acquisition period extends until later than 3;3 years (the age of the oldest participant). Although some children master word-initial CC before age 3;3, others do not start producing word-initial CCs until later than age 2;2. Further studies that aim to define the window of Catalan word-initial CC acquisition should target a wider age range. Moreover, a preliminary study that allows to calculate the level of linguistic development of each participant (e.g., mean length of utterance, vocabulary size…) would be interesting to assess performance based on other factors besides age alone.

6.1 Discussion of theoretical implications

Jongstra (2003)'s account is based on the prosodification of the syllable, thus distinguishing two stages in word-initial complex onset acquisition: stage 1, where the head of the cluster is selected based on sonority, and stage 2, where the head is selected based on syllabic structure combined with a more fine-tuned notion of sonority that allows for the distinction between /ɾ/ and /l/. Jongstra's account takes /s/C clusters as the point of departure to move from stage 1 to stage 2. This might imply that either children acquiring languages with no /s/C clusters, such as Catalan, do not undergo stage 2; or that stage 2 is reached through a different process in such languages. The relevant difference between stage 1 and stage 2 for Catalan is that in stage 1 the [fl, fɾ] are predicted to be reduced to C1 consistently, whereas in stage 2 variation in the reduction pattern is predicted. That is, in stage 2 reduction to C1(i.e., production of [fl] as [f]) and reduction to C2 (i.e., production of [fl] as [l]) are both expected. The data from the present study seems to point that Catalan children do not undergo stage 2, since no variation in the CR reduction pattern was found for [fl, fɾ]. Another issue with Jongstra's account is that stage 2 is proposed as the gateway to adult-like productions. If Jongstra's proposal is to be defended, there needs to be some account of how children acquiring languages that do not allow word-initial /s/C clusters reach adult-like productions.

Pater & Barlow (2002)'s proposal is more accurate in predicting the performance of word-initial CCs in Catalan. Their account is based on the interaction of a set of phonetically grounded constraints, ordered according to relative sonority, which leads to selection of the least sonorous element in a CR (i.e., cluster reduction). The data in the study shows that while the difference in sonority between Catalan /ɾ/ and /l/ is relevant to predict TC performance, it is not relevant for the CR pattern, since clusters are always reduced to C1. However, one of the main issues with Pater & Barlow's account was that they did not treat liquids as distinct units, failing to predict the variability in CR patterns found by Jongstra (2003) for Dutch. In this sense, a way to improve Pater & Barlow's proposal would be to divide *L-ONS in two different constraints. That is, */ɾ/-ONS and */l/-ONS, ranked together in Catalan but offering some variation in Dutch. Hence, the constraint ranking in (4) would be reformulated as (20) for Catalan and as (21) for Dutch.

(20) *GLIDE-ONSET >> */l/-ONSET, */ɾ /-ONSET >> *NASAL-ONSET >> *FRICATIVE-ONSET

(21) *GLIDE-ONSET >> */l/-ONSET >> */ɾ /-ONSET >> *NASAL-ONSET >> *FRICATIVE-ONSET

The last issue with both proposals, namely that they do not establish how adult-like realizations are achieved, cannot be resolved with the data provided here, since the age range included in the study was not wide enough to distinguish a phase where adult-like realizations are achieved. However, our results are consistent with the reported improvement of CC production around 2;2-2;5 reported by Pressier et al (1988) and Lleó & Prinz (1996).

7 CONCLUSION

Summing up, in the present study I have offered some initial findings of word-initial complex onset acquisition in Catalan. The analysis of the data collected has led to a series of conclusions. Firstly, that Catalan children consistently reduce word-initial CCs to C1, never to C2. Secondly, the results have shown that Catalan children do not acquire all clusters at the same time, but rather that there is a hierarchy regarding the acquisition of word-initial CCs. This hierarchy is mainly affected by relative sonority between the consonants in the cluster, favoring the production of clusters where the distance in sonority is higher. This also provides evidence for difference in sonority between /ɾ/ and /l/ in Catalan (/ɾ/ being more sonorous than /l/), a difference that becomes relevant when it comes to word-initial CC acquisition. Thus, C/l/ clusters are more easily produced than C/ɾ/ clusters. Nonetheless, it has been seen that children do not have a straight path of word-initial CC acquisition, since production of CCs was not always within-cluster stable, often showing different mechanisms for the realization of the same cluster (e.g., participant 18 produces the whole [tɾ] cluster in *tren* 'train' and *tractor* 'tractor' but reduces the cluster to C1 for *tres* 'three'). Hence, different word-initial CC production mechanisms coexist in a child's language, at least during a certain timespan. A third main conclusion is that frequency of the cluster in the child's environment plays no role in acquisition, at least for our dataset. By contrast, relative sonority of the cluster seems to be the main factor that allows to predict adult-like production. When it comes to fitting the results found in the present study to the previous work on word-initial CC acquisition, it seems that Pater & Barlow's account is the more fitting to predict (and not over-predict) the data from Catalan complex onset production.

For further research, it would be interesting to consider a wider range of ages in the participants of the study, starting before 2 years and ending past the age of 3. In addition, performing sessions with the same children over a prolonged span of time (à la Jongstra 2003) would allow to define for how long different mechanisms are used for word-initial CC production and at what age children discard other processes and resolve to TC. Secondly, it would be interesting to perform a perception study to see if production and perception go hand in hand for word-initial CC acquisition (for instance, based on the work of Gulian et al. 2014). Finally, I have not been able to discuss in depth consonant substitution for ≠C1 and CR≠C1. This remains for future research.

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APPENDICES

APPENDIX 1

Complete set of images shown for the experiment

Page 1

Page 2

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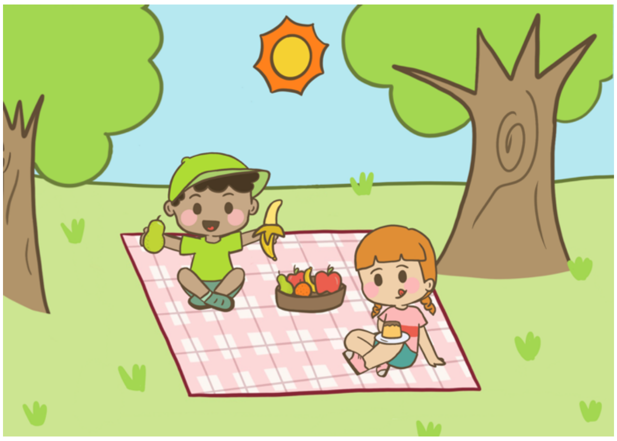

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APPENDIX 2

Frequencies of the target words in the *DF* and the analysed CHILDES database. The analysis of the CHILDES database was made through programming using Jupiter Notebook. It is to be taken as an approximation rather than an exact measure, since the program's scrutiny does not match a trained eye. In both cases, words that share the same lemma were included in the frequency count. Thus, words such as *trenet* 'little train' are included in the frequency of *train* 'tren'. The word *front* 'forehead' was excluded from the CHILDES counting because some of the annotations in the transcriptions were in English and the program created did not allow to distinguish between the English *front* and the Catalan *front*. Finally, the proper name *Clara* was not distinguished from the adjective *clar* 'light'.

The term *absolute freq(quency)* refers to the total iterations of the word, whereas *relative freq(uency)* refers to the frequency of the word in relation to the total of words included in the dictionary, up to two decimals.

	CHILDES		**DDF**	
item	*absolute freq.*	*relative freq.*	*absolute freq.*	*relative freq.*
prim	1	0.00%	1323	0.00%
prat	6	0.00%	997	0.00%
primer	252	0.11%	43739	0.15%
plora	360	0.15%	1049	0.00%
plàtan	132	0.06%	183	0.00%
plou	72	0.03%	657	0.00%
tren	105	0.05%	877	0.00%
tres	258	0.11%	17908	0.06%
tractor	127	0.05%	114	0.00%
crema	194	0.08%	1973	0.01%
cranc	0	0%	220	0.00%
crida	235	0.73%	3145	0.01%
Clara	94	0.04%	141	0.00%
clau	20	0.01%	904	0.03%
closca	6	0.00%	81	0.00%
fred	86	0.04%	2200	0.01%
front	7	0.00%	2312	0.01%
fruita	27	0.01%	1386	0.00%
fletxa	4	0.00%	183	0.00%
flor	45	0.19%	4552	0.02%
flam	29	0.01%	50	0.00%
Total frequency	2053	1.68%	83994	0.32%

APPENDIX 3

APPENDIX 3.1

Individual results of the experiment spreadsheet for the VCV condition.
(*NR*=no response; *D*=distractor; *Other*=other responses; *T*=target consonant; *≠C*=consonant shift(specified); *ØC*=no consonant).

	V[ɾ]V		V[r]V		V[l]V	
	pera	cara	gorra	sorra	pilota	pala
Child 22 (2;2;1)	T	T	≠C [ɾ]	≠C [ɾ - j]	T	NR
Child 24 (2;2;28)	T	≠C [ð]	≠C [l]	NR	T	T
Child 4 (2;6;22)	T	≠C [r]	T	T	T	T
Child 1 (2;6;24)	≠C [j]	NR	≠C [ɾ]	NR	ØC	NR
Child 30 (2;7;18)	T	T	D	≠C [ɾ]	T	T
Child 20 (2;7;30)	≠C [ð]	≠C [ð]	Other	NR	T	T
Child 5 (2;7;30)	≠C [ɣ]	≠C [β]	ØC	≠C [β]	T	T
Child 26 (2;9;9)	≠C [l]	≠C [l]	≠C [l]	≠C [l]	T	T
Child 17 (2;9;10)	≠C [l]	T	≠C [ɾ]	≠C [ð]	T	T
Child 18 (2;9;19)	T	T	≠C [ɾ]	NR	T	T
Child 23 (2;10;1)	T	T	≠C [ɾ]	≠C [ɾ]	T	T
Child 8 (2;20;8)	T	T	≠C [ɾ]	≠C [ɾ]	T	T
Child 29 (2;10;12)	T	T	≠C [l]	≠C [l]	T	T
Child 28 (2;10;15)	≠C [ð]	T	≠C [ɾ]	≠C [ɾ]	T	T
Child 13 (2;10;21)	T	≠C [r]	T	≠C [ɾ]	T	T
Child 19 (2;10;23)	T	Other	≠C [ɾ]	NR	ØC	ØC
Child 3 (2;11;11)	≠C [l]	NR	≠C [l]	≠C [l]	T	T
Child 6 (2;11;24)	T	T	NR	T	T	T
Child 9 (2;11;25)	T	T	≠C [ɾ]	≠C [ɾ]	D	T
Child 15 (3;0;12)	Other	NR	D	≠C [β]	T	NR
Child 25 (3;0;13)	T	T	≠C [ɾ]	T	T	T
Child 27 (3;0;25)	≠C [j]	T	≠C [l]	≠C [ɾ]	T	T
Child 12 (3;1;6)	≠C [ð]	T	T	T	T	T
Child 7 (3;1;14)	T	T	T	NR	T	T
Child 11 (3;2;6)	T	T	≠C [ɾ]	NR	T	T
Child 10 (3;3;8)	≠C [ð]	≠C [ð]	≠C [ð]	NR	T	T
Child 2 (3;3;18)	T	Other	≠C [ɾ]	T	T	T

APPENDIX 3.2

Individual results of the experiment spreadsheet for the word-initial CC condition.
(*NR*=no response; *D*=distractor; *Other*=other responses; *TC*=target cluster; *≠C1*=complex cluster with C1 shift(specified); *≠C2*=complex cluster with C2 shift(specified) *CR*=cluster reduction; *CR≠C1*=cluster reduction with shift of C1(specified); *CR:*=cluster reduction with vowel lengthening; *ØC*=no consonant).

	[tɾ]			[pɾ]			[pl]			[fɾ]			[fl]			[kɾ]			[kl]		
	tren	tractor	tres	prat	prim	primer	plora	plàtan	plou	front	fruita	fred	flors	fletxa	flam	crema	cranc	crida	Clara	closca	clau
Child 22 (2;2;1)	NR	CR	CR	TC	CR	D	CR	CR	TC	≠C2 [fl]	NR	D	TC	TC	Other	CR	CR	NR	CR	CR	CR
Child 24 (2;2;28)	CR	CR	CR	D	CR	D	CR	CR	CR	CR	CR ≠C1 [p]	CR	CR	CR	CR	CR	CR	CR	CR	CR	CR
Child 4 (2;6;22)	TC	TC	Other	≠C2 [pr]	NR	NR	TC	Other	TC	NR	NR	D	TC	≠C1 [pl]	Other	TC	TC	TC	D	TC	TC
Child 1 (2;6;24)	CR	CR	CR	CR	CR	CR	D	CR	NR	CR	CR ≠C1 [p]	NR	CR	CR	CR	NR	CR	NR	CR	NR	NR
Child 30 (2;7;18)	TC	TC	TC	Other	TC	D	TC	TC	TC	CR	CR	TC	TC	Other	Other	TC	≠C2 [kr]	D	TC	TC	TC
Child 20 (2;7;30)	CR	CR	Other	Other	NR	NR	Other	CR	CR	CR	NR	CR ≠C1 [ʃ]	NR	Other	CR ≠C1 [t]	CR ≠C1 [t]	CR ≠C1 [t]	NR	CR ≠C1 [t]	Other	CR ≠C1 [t]
Child 5 (2;7;30)	CR	CR	CR	CR	CR	CR	TC	TC	TC	CR	CR	CR	CR	TC	TC	CR	CR	CR	TC	TC	TC
Child 26 (2;9;9)	CR	CR	CR	Other	CR	CR	TC	TC	TC	≠C2 [fl]	TC	≠C2 [fl]	TC	TC	TC	≠C2 [kl]	≠C2 [kl]	CR	TC	TC	TC
Child 17 (2;9;10)	CR	≠C2 [tð]	CR	D	CR	D	CR	TC	CR	≠C2 [fð]	CR	D	TC	TC	TC	≠C2 [kl]	TC	CR	TC	TC	CR
Child 18 (2;9;19)	TC	TC	CR	TC	TC	D	TC	TC	TC	TC	TC	CR	NR	D	D	TC	TC	TC	TC	TC	TC
Child 23 (2;10;1)	TC	D	CR	D	≠C2 [pð]	D	TC	TC	TC	Other	Other	CR ≠C1 [p]	≠C1 [pl]	Other	≠C1 [pl]	TC	TC	CR	TC	TC	TC
Child 8 (2;20;8)	CR	NR	CR	NR	CR	CR ≠C1 [t]	TC	CR	CR	CR	CR	CR	CR	D	ØC	CR	CR	CR ≠C1 [t]	CR ≠C1 [t]	CR ≠C1 [t]	CR
Child 29 (2;10;12)	CR	CR	CR	D	CR	D	CR	CR	CR	TC	CR ≠C1 [p]	D	CR ≠C1[β]	D	≠C1 [bl]	CR	CR	CR	CR	CR	CR
Child 28 (2;10;15)	D	CR	CR:	D	D	CR	CR	CR	TC	CR	CR	D	TC	D	CR	CR ≠C1 [t]	CR ≠C1 [t]	CR	TC	CR	TC
Child 13 (2;10;21)	TC	≠C2 [tð]	TC	NR	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	NR	CR	TC
Child 19 (2;10;23)	CR:	CR	CR:	CR:	D	NR	CR	NR	TC	CR	D	CR	Other	CR	D	NR	CR :	Other	TC	CR	CR ≠C1 [p]
Child 3 (2;11;11)	CR	CR	CR	≠C2 [pl]	NR	CR	CR	TC	NR	CR ≠C1 [p]	CR	CR ≠C1 [p]	CR	CR	≠C1 [pl]	CR	CR	NR	CR	≠C1 [χl]	TC
Child 6 (2;11;24)	TC	D	TC	Other	D	D	TC	TC	TC	TC	Other	TC	NR	Other	Other	TC	TC	TC	TC	TC	D
Child 9 (2;11;25)	CR	CR	CR	D	Other	D	≠C2 [pɾ]	TC	TC	≠C1 [pɾ]	CR	≠C2 [fð]	≠C1 [pl]	≠C1 [pl]	TC	TC	TC	NR	TC	D	TC
Child 15 (3;0;12)	CR	≠C2 [tð]	CR	≠C2 [pl]	NR	NR	Other	TC	CR	Other	CR ≠C1 [t]	CR ≠C1 [t]	≠C1 [pl]	NR	NR	CR	NR	D	CR	Other	NR
Child 25 (3;0;13)	TC	TC	CR	TC	TC	TC	TC	TC	TC	Other	CR	CR	TC	TC	Other	TC	TC	TC	TC	TC	TC
Child 27 (3;0;25)	CR	CR	CR	CR	CR	NR	CR	CR	CR	CR	CR	CR	CR	D	CR	CR ≠C1 [t]	CR ≠C1 [l]	CR ≠C1 [t]	CR	CR	CR ≠C1 [t]
Child 12 (3;1;6)	TC	≠C2 [tð]	≠C2 [tð]	≠C2 [pð]	TC	TC	TC	TC	TC	≠C2 [fð]	≠C2 [fð]	≠C2 [fð]	TC	D	TC	TC	TC	TC	TC	TC	TC
Child 7 (3;1;14)	TC	CR	CR	≠C2 [pl]	TC	CR	TC	TC	TC	TC	CR	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC
Child 11 (3;2;6)	TC	TC	TC	≠C1 [tɾ]	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	≠C2 [fɾ]	TC	TC	≠C2 [kl]	TC	≠C2 [kɾ]	TC
Child 10 (3;3;8)	CR	CR	CR	CR	NR	CR	CR	CR	CR	CR	CR ≠C1 [p]	CR ≠C1 [t]	CR ≠C1 [t]	Other	CR ≠C1 [t]	CR ≠C1 [t]	CR ≠C1 [t]	CR ≠C1 [t]	CR ≠C1 [t]	CR ≠C1 [t]	CR ≠C1 [t]
Child 2 (3;3;18)	TC	CR	TC	≠C2 [pr]	CR	TC	TC	TC	TC	TC	≠C2 [fr]	TC	≠C1[βl]	TC	Other	≠C2 [kr]	≠C2 [kr]	TC	TC	TC	TC

APPENDIX 4

APPENDIX 4.1

Frequency of each mechanism and NR for word-initial CC.
Percentages calculated for the number of total word-initial CC items per condition (n=81).

	NR		TC		≠C1		≠C2		CR		CR≠C1		CR:		ØC	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
[pɾ]	35	43.21	15	18.52	1	1.23	7	8.64	21	25.93	1	1.23	1	1.23	0	0.00
[pl]	11	13.58	47	58.02	0	0.00	1	1.23	24	29.63	0	0.00	0	0.00	0	0.00
[tɾ]	7	8.64	21	25.93	0	0.00	5	6.17	45	55.56	0	0.00	3	3.70	0	0.00
[kɾ]	11	13.58	30	37.04	0	0.00	7	8.64	21	25.93	11	13.58	1	1.23	0	0.00
[kl]	9	11.11	42	51.85	1	1.23	1	1.23	19	23.46	9	11.11	0	0.00	0	0.00
[fɾ]	16	19.75	17	20.99	1	1.23	9	11.11	27	33.33	11	13.58	0	0.00	0	0.00
[fl]	25	30.86	27	33.33	9	11.11	1	1.23	14	17.28	4	4.94	0	0.00	1	1.23

APPENDIX 4.2

Frequency of each mechanism and NR for item.
Percentages calculated considering the number of participants (n=27).

	NR		TC		≠C1		≠C2		CR		CR≠C1		CR:		ØC	
	n	%	n	%	N	%	n	%	n	%	n	%	n	%	n	%
prat	12	44.44	5	18.52	1	3.70	6	22.22	4	14.81	0	0.00	1	3.70	0	0.00
prim	9	33.33	7	25.93	0	0.00	1	3.70	10	37.04	0	0.00	0	0.00	0	0.00
primer	14	51.85	5	18.52	0	0.00	0	0.00	7	25.93	1	3.70	0	0.00	0	0.00
plora	3	11.11	14	51.85	0	0.00	1	3.70	9	33.33	0	0.00	0	0.00	0	0.00
plàtan	2	7.41	16	59.25	0	0.00	0	0.00	9	33.33	0	0.00	0	0.00	0	0.00
plou	2	7.41	17	62.96	0	0.00	0	0.00	8	29.63	0	0.00	0	0.00	0	0.00
tren	2	7.41	11	40.74	0	0.00	0	0.00	13	48.14	0	0.00	1	3.70	0	0.00
tractor	3	11.11	5	18.52	0	0.00	4	14.81	15	55.55	0	0.00	0	0.00	0	0.00
tres	2	7.41	5	18.52	0	0.00	1	3.70	17	62.96	0	0.00	2	7.41	0	0.00
crema	2	7.41	11	40.74	0	0.00	3	11.11	7	25.93	4	14.81	0	0.00	0	0.00
cranc	1	3.70	11	40.74	0	0.00	3	11.11	7	25.93	4	14.81	1	3.70	0	0.00
crida	8	29.63	8	29.63	0	0.00	1	3.70	7	25.93	3	11.11	0	0.00	0	0.00
Clara	2	7.41	2	7.41	0	0.00	0	0.00	7	25.93	3	11.11	0	0.00	0	0.00
closca	4	14.81	4	14.81	1	3.70	1	3.70	7	25.93	2	7.41	0	0.00	0	0.00
clau	3	11.11	3	11.11	0	0.00	0	0.00	5	18.52	4	14.81	0	0.00	0	0.00
front	4	14.81	7	25.93	1	3.70	4	14.81	10	37.04	1	7.41	0	0.00	0	0.00
fruita	6	22.22	4	14.81	0	0.00	2	7.41	10	37.04	5	18.52	0	0.00	0	0.00
fred	6	22.22	6	22.22	0	0.00	3	11.11	7	25.93	5	18.52	0	0.00	0	0.00
flors	4	14.81	11	40.74	4	14.81	0	0.00	6	22.22	2	7.41	0	0.00	0	0.00
fletxa	12	44.44	9	33.33	2	7.41	0	0.00	4	14.81	0	0.00	0	0.00	0	0.00
flam	9	33.33	7	25.93	3	11.11	1	3.70	4	14.81	2	7.41	0	0.00	1	3.70

APPENDIX 5

Frequency of each mechanism and NR per participant.
Percentages calculated considering the number of target items (n=21).

	NR		TC		≠C1		≠C2		CR		CR≠C1		CR:		ØC	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
22	6	28.57	4	19.05	0	0.00	1	4.76	10	47.62	0	0.00	0	0.00	0	0.00
24	2	9.52	0	0.00	0	0.00	0	0.00	18	85.71	1	4.76	0	0.00	0	0.00
4	9	42.86	10	47.62	1	4.76	1	4.76	0	0.00	0	0.00	0	0.00	0	0.00
1	7	33.33	0	0.00	0	0.00	0	0.00	13	61.90	1	4.76	0	0.00	0	0.00
30	5	23.81	13	61.90	0	0.00	1	4.76	2	9.52	0	0.00	0	0.00	0	0.00
20	10	47.62	0	0.00	0	0.00	0	0.00	5	23.81	6	28.57	0	0.00	0	0.00
5	0	0.00	8	38.10	0	0.00	0	0.00	13	61.90	0	0.00	0	0.00	0	0.00
26	1	4.76	10	47.62	0	0.00	4	19.05	6	28.57	0	0.00	0	0.00	0	0.00
17	3	14.29	7	33.33	0	0.00	3	14.29	8	38.10	0	0.00	0	0.00	0	0.00
18	4	19.05	15	71.43	0	0.00	0	0.00	2	9.52	0	0.00	0	0.00	0	0.00
23	6	28.57	9	42.86	2	9.52	1	4.76	2	9.52	1	4.76	0	0.00	0	0.00
8	3	14.29	1	4.76	0	0.00	0	0.00	12	57.14	4	19.05	0	0.00	1	4.76
29	4	19.05	1	4.76	1	4.76	0	0.00	13	61.90	2	9.52	0	0.00	0	0.00
28	5	23.81	4	19.05	0	0.00	0	0.00	9	42.86	2	9.52	1	4.76	0	0.00
13	2	9.52	17	80.95	0	0.00	1	4.76	1	4.76	0	0.00	0	0.00	0	0.00
19	8	38.10	2	9.52	0	0.00	0	0.00	6	28.57	1	4.76	4	19.05	0	0.00
3	3	14.29	2	9.52	2	9.52	1	4.76	11	52.38	2	9.52	0	0.00	0	0.00
6	9	42.86	12	57.14	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
9	5	23.81	7	33.33	3	14.29	2	9.52	4	19.05	0	0.00	0	0.00	0	0.00
15	10	47.62	1	4.76	1	4.76	2	9.52	5	23.81	2	9.52	0	0.00	0	0.00
25	2	9.52	16	76.19	0	0.00	0	0.00	3	14.29	0	0.00	0	0.00	0	0.00
27	2	9.52	0	0.00	0	0.00	0	0.00	15	71.43	4	19.05	0	0.00	0	0.00
12	1	4.76	14	66.67	0	0.00	6	28.57	0	0.00	0	0.00	0	0.00	0	0.00
7	0	0.00	16	76.19	0	0.00	1	4.76	4	19.05	0	0.00	0	0.00	0	0.00
11	0	0.00	17	80.95	1	4.76	3	14.29	0	0.00	0	0.00	0	0.00	0	0.00
10	2	9.52	0	0.00	0	0.00	0	0.00	9	42.86	10	47.62	0	0.00	0	0.00
2	1	4.76	13	61.90	1	4.76	4	19.05	2	9.52	0	0.00	0	0.00	0	0.00

APPENDIX 6

APPENDIX 6.1

Frequency of each mechanism and NR for word-initial CC per age group

Percentages calculated considering the number of total word-initial CC items per condition (n=57 for the 2;8 age group and n=24 for the 3;1 age group).

		NR		TC		≠C1		≠C2		CR		CR≠C1		CR:		ØC	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
[pɾ]	2;8	31	54.39	6	10.53	0	0.00	3	5.26	15	26.32	1	1.75	1	1.75	0	0.00
	3;1	4	16.67	9	37.50	1	4.17	4	16.67	6	25.00	0	0.00	0	0.00	0	0.00
[pl]	2;8	8	14.04	35	61.40	1	1.75	4	7.02	19	33.33	1	1.75	0	0.00	0	0.00
	3;1	1	4.17	16	66.67	0	0.00	0	0.00	7	29.17	0	0.00	0	0.00	0	0.00
[tɾ]	2;8	7	12.28	12	21.05	0	0.00	2	3.51	33	57.89	0	0.00	3	5.26	0	0.00
	3;1	0	0.00	9	37.50	0	0.00	3	12.50	12	50.00	0	0.00	0	0.00	0	0.00
[kɾ]	2;8	9	15.79	18	31.58	0	0.00	4	7.02	20	35.09	5	8.77	1	1.75	0	0.00
	3;1	2	8.33	12	50.00	0	0.00	3	12.50	1	4.17	6	25.00	0	0.00	0	0.00
[kl]	2;8	7	12.28	28	49.12	1	1.75	0	0.00	16	28.07	5	8.77	0	0.00	0	0.00
	3;1	2	8.33	14	58.33	0	0.00	1	4.17	3	12.50	4	16.67	0	0.00	0	0.00
[fɾ]	2;8	14	24.56	10	17.54	1	1.75	5	8.77	20	35.09	7	12.28	0	0.00	0	0.00
	3;1	2	8.33	7	29.17	0	0.00	4	16.67	7	29.17	4	16.67	0	0.00	0	0.00
[fl]	2;8	18	31.58	17	29.82	7	12.28	0	0.00	12	21.05	2	3.51	0	0.00	1	1.75
	3;1	7	29.17	10	41.67	2	8.33	1	4.17	2	8.33	2	8.33	0	0.00	0	0.00

APPENDIX 6.2

Frequency each mechanism and NR for item per age group

Percentages calculated considering the number of participants (n=19 for the 2;8 age group and n=8 for the 3;1 age group).

		NR		TC		≠C1		≠C2		CR		CR≠C1		CR:		ØC	
		n	%	n	%	N	%	n	%	n	%	n	%	n	%	n	%
prat	2;8	12	63.13	2	10.53	0	0.00	2	10.53	2	10.53	0	0.00	1	5.26	0	0.00
	3;1	0	0.00	1	12.50	1	12.50	4	50.00	1	12.50	0	0.00	0	0.00	0	0.00
prim	2;8	7	36.84	3	15.79	0	0.00	1	5.26	8	42.11	0	0.00	0	0.00	0	0.00
	3;1	2	25.00	4	50.00	0	0.00	0	0.00	2	25.00	0	0.00	0	0.00	0	0.00
primer	2;8	12	63.13	1	5.26	0	0.00	0	0.00	5	26.32	1	5.26	0	0.00	0	0.00
	3;1	2	25.00	4	50.00	0	0.00	0	0.00	2	25.00	0	0.00	0	0.00	0	0.00

plora	2;8	2	10.53	9	47.37	0	0.00	1	5.26	7	36.84	0	0.00	0	0.00	0	0.00
	3;1	1	12.50	5	62.50	0	0.00	0	0.00	2	25.00	0	0.00	0	0.00	0	0.00
plàtan	2;8	2	10.53	10	52.63	0	0.00	0	0.00	7	36.84	0	0.00	0	0.00	0	0.00
	3;1	0	0.00	6	75.00	0	0.00	0	0.00	3	37.50	0	0.00	0	0.00	0	0.00
plou	2;8	2	10.53	12	63.13	0	0.00	0	0.00	5	26.32	0	0.00	0	0.00	0	0.00
	3;1	0	0.00	5	62.50	0	0.00	0	0.00	3	37.50	0	0.00	0	0.00	0	0.00
tren	2;8	2	10.53	6	31.58	0	0.00	0	0.00	10	52.63	0	0.00	1	5.26	0	0.00
	3;1	0	0.00	5	62.50	0	0.00	0	0.00	3	37.50	0	0.00	0	0.00	0	0.00
tractor	2;8	3	15.79	3	15.79	0	0.00	2	10.53	11	57.89	0	0.00	0	0.00	0	0.00
	3;1	0	0.00	2	25.00	0	0.00	2	25.00	4	50.00	0	0.00	0	0.00	0	0.00
tres	2;8	2	10.53	3	15.79	0	0.00	0	0.00	12	63.13	0	0.00	2	10.53	0	0.00
	3;1	0	0.00	2	25.00	0	0.00	1	12.50	5	62.50	0	0.00	0	0.00	0	0.00
crema	2;8	2	10.53	7	36.84	0	0.00	2	10.53	6	31.58	2	10.53	0	0.00	0	0.00
	3;1	0	0.00	4	50.00	0	0.00	1	12.50	1	12.50	2	25.00	0	0.00	0	0.00
cranc	2;8	0	0.00	7	36.84	0	0.00	2	10.53	7	36.84	2	10.53	1	5.26	0	0.00
	3;1	1	12.50	4	50.00	0	0.00	1	12.50	0	0.00	2	25.00	0	0.00	0	0.00
crida	2;8	7	36.84	4	21.05	0	0.00	0	0.00	7	36.84	1	5.26	0	0.00	0	0.00
	3;1	1	12.50	4	50.00	0	0.00	1	12.50	0	0.00	2	25.00	0	0.00	0	0.00
Clara	2;8	2	10.53	10	52.63	0	0.00	0	0.00	5	26.32	2	10.53	0	0.00	0	0.00
	3;1	0	0.00	5	62.50	0	0.00	0	0.00	2	25.00	1	12.50	0	0.00	0	0.00
closca	2;8	3	15.79	8	42.11	1	5.26	0	0.00	6	31.58	1	5.26	0	0.00	0	0.00
	3;1	1	12.50	4	50.00	0	0.00	1	12.50	1	12.50	1	12.50	0	0.00	0	0.00
clau	2;8	2	10.53	10	52.63	0	0.00	0	0.00	5	26.32	2	10.53	0	0.00	0	0.00
	3;1	1	12.50	5	62.50	0	0.00	0	0.00	0	0.00	2	25.00	0	0.00	0	0.00
front	2;8	2	10.53	4	21.05	1	5.26	3	15.79	8	42.11	1	5.26	0	0.00	0	0.00
	3;1	2	25.00	3	37.50	0	0.00	1	12.50	2	25.00	0	0.00	0	0.00	0	0.00
fruita	2;8	6	31.58	3	15.79	0	0.00	0	0.00	7	36.84	3	15.79	0	0.00	0	0.00
	3;1	0	0.00	1	12.50	0	0.00	2	25.00	3	37.50	2	25.00	0	0.00	0	0.00
fred	2;8	6	31.58	3	15.79	0	0.00	2	10.53	5	26.32	3	15.79	0	0.00	0	0.00
	3;1	0	0.00	3	37.50	0	0.00	1	12.50	2	25.00	2	25.00	0	0.00	0	0.00
flors	2;8	4	21.05	7	36.84	2	10.53	0	0.00	5	26.32	1	5.26	0	0.00	0	0.00
	3;1	0	0.00	4	50.00	2	25.00	0	0.00	1	12.50	1	12.50	0	0.00	0	0.00
fletxa	2;8	8	42.11	8	42.11	2	10.53	0	0.00	4	21.05	0	0.00	0	0.00	0	0.00
	3;1	4	50.00	4	50.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
flam	2;8	6	31.58	5	26.32	3	15.79	0	0.00	3	15.79	1	5.26	0	0.00	1	5.26
	3;1	3	37.50	2	25.00	0	0.00	1	12.50	1	12.50	1	12.50	0	0.00	0	0.00

APPENDIX 6.3

Figures 4.1-4.7 display the number of times each mechanism was used for each of the three items per condition.

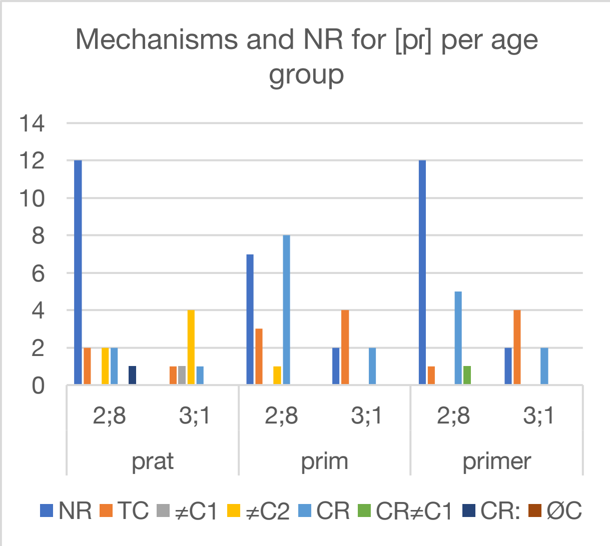

Figure 4.1. Mechanisms and NR for [pɾ] per age group

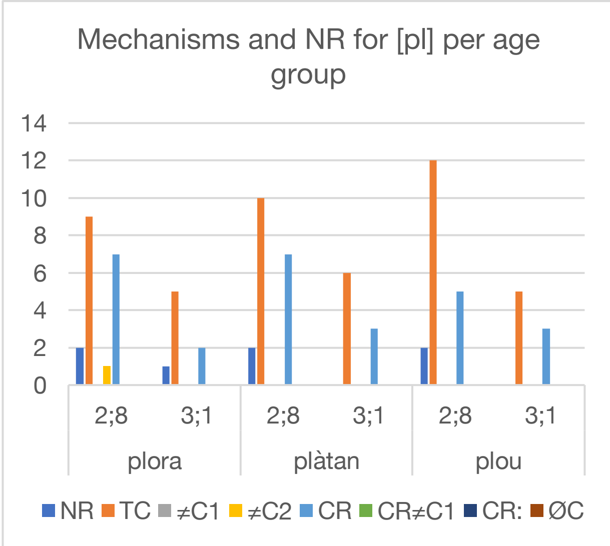

Figure 4.2. Mechanisms and NR for [pl] per age group

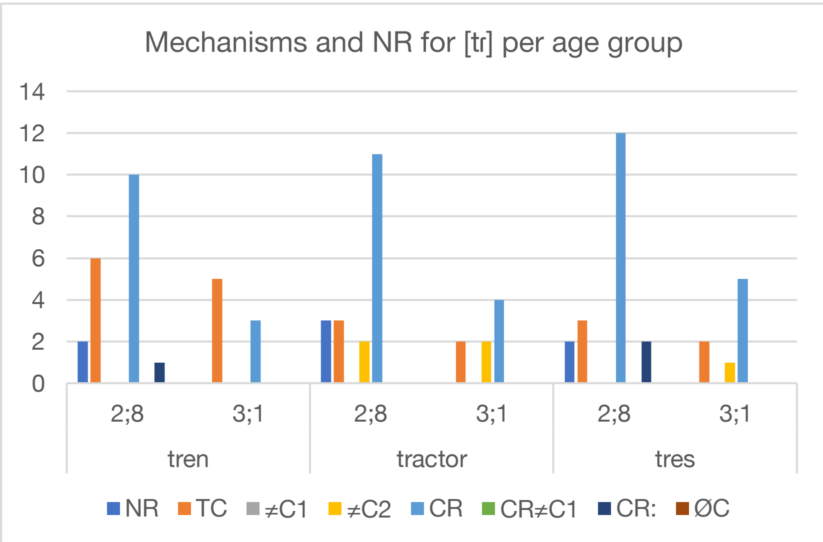

Figure 4.3.Mechanisms and NR for [tɾ] per age group

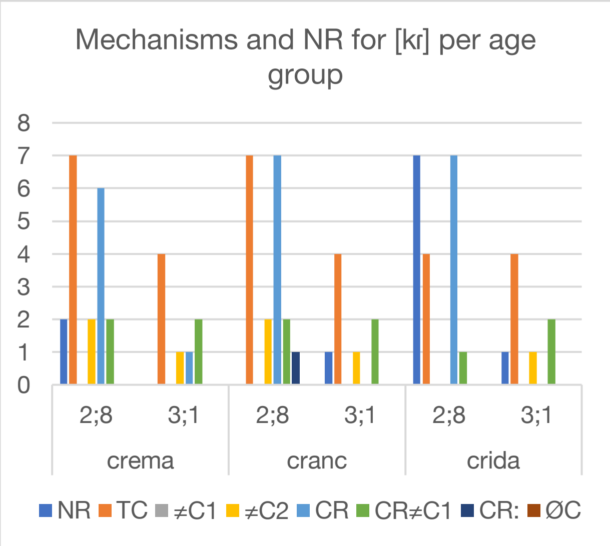

Figure 4.4. Mechanisms and NR for [kɾ] per age group

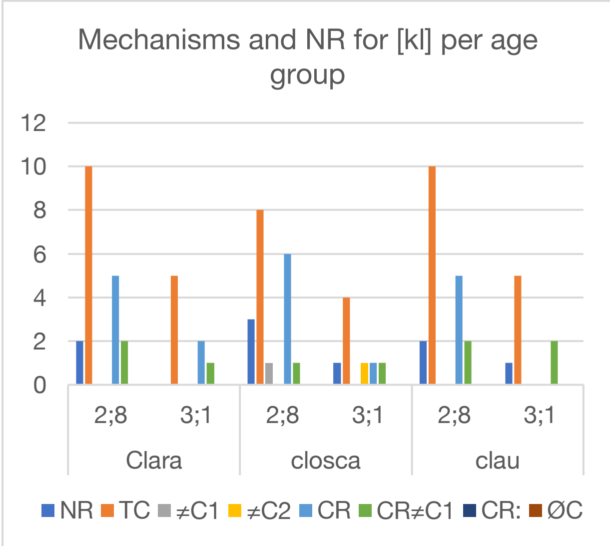

Figure 4.5. Mechanisms and NR for [kl] per age group

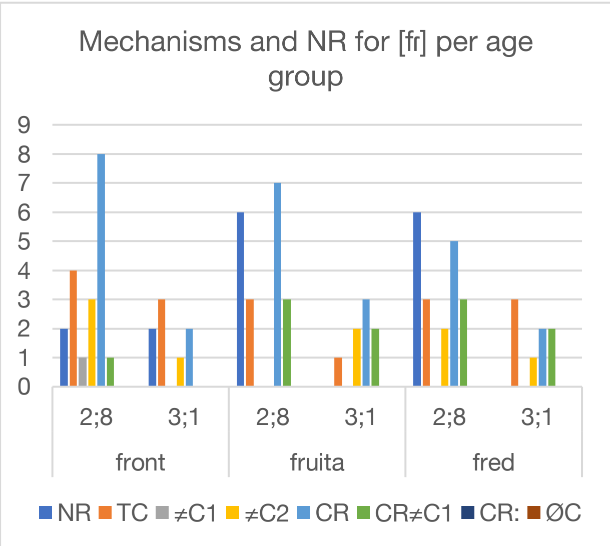

Figure 4.6. Mechanisms and NR for [fɾ] per age group

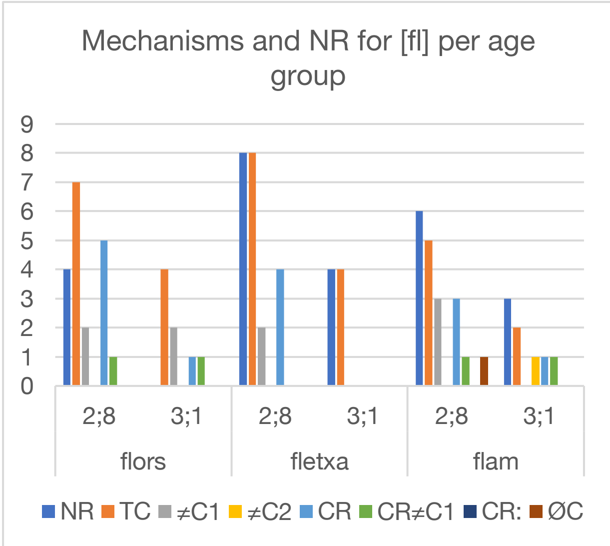

Figure 4.7. Mechanisms and NR for [fl] per age group