Word-initial consonant clusters in Latvian child language: variation, sonority and grammar stratification

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Abstract

The strategies displayed by 20 Latvian children who avoid complex word-initial onsets that we present in this paper, pose problems for previous accounts of cluster reduction. We propose an optimality-theoretic analysis based on constraints on complex onsets derived from typological observations, in which we crucially have to assume that these children syllabify the complex onsets correctly at an abstract level and then reduce them in a later stratum of the grammar. This paper shows, thus, that stratification of grammar leads to effects in language acquisition even in phonotactic learning.

1 Introduction

Children's early speech productions are characterized by structural simplicity. In the realm of prosody, this means that syllable inventories start out containing only unmarked syllable types (e.g. CV) and are gradually expanded to include more complex structures (Fikkert 1994, Levelt, Schiller & Levelt 2000). This entails that in the course of phonological acquisition all children go through the stage where complex structures of the ambient language – e.g. branching onsets – are transformed to conform to the pattern(s) allowed by the current state of a child´s grammar. When it comes to onset clusters, one of the most common transformation strategies employed by young children is cluster reduction – i.e. the situation where only one of the elements of the input cluster survives in the output of a child´s grammar. Which one of the two elements is deleted and which one is retained is determined by the constraint ranking characterizing a given developmental stage (if we assume Optimality Theory – Prince & Smolensky 1993/2004). It has been reported that certain reduction patterns – i.e. reduction of all complex onsets to the least sonorous element – are cross-linguistically prevalent, while other logically possible patterns are virtually unattested (Fikkert 1994, Gnanadesikan 1995/2004, Gierut 1999, Pater & Barlow 2003 among others). To account for the existence of these seemingly universal tendencies, it has been proposed that constraint ranking is subject to certain innate biases. One of the ranking biases generally invoked in OT literature is the bias of the Initial State, by which all markedness constraints are said to outrank all faithfulness constraints before the onset of phonological acquisition (Gnanadesikan 1995/2004 for example). While the bias of the Initial State accounts for the pervasiveness of cluster reduction in child phonology (by appealing to the universal early *Complex >> MAX ranking), in itself it cannot explain the attested cross-linguistic tendencies to preserve certain segment types while deleting the others. To deal with this latter phenomenon, researchers have resorted to Prince & Smolensky's (1993/2004) universal rankings of constraints that determine the wellformedness of onsets by their sonority. For instance, Barlow (2001b:301) appeals to the universal ranking where *M/SON, a constraint penalizing sonorants parsed in syllable margins, dominates *M/OBSTR, militating against obstruents in the same position. As illustrated in (1), this ranking has an effect of an output preserving the obstruent always being more harmonic than that preserving the sonorant.

(1) Universal ranking and onset harmony

	*COMPLEX	*MARGIN/SONORANT	*MARGIN/OBSTRUENT
a. bla	*!	*	*
b. la		*!	
c. ba			*

Note that since the ranking of *M/SON above *M/OBSTR is universally fixed, the analysis in (1) predicts that the pattern where candidate (b) wins the evaluation is unattestable. However, it goes without saying that the situation in natural languages is far more complex than that illustrated with the toy grammar above. The pattern in which clusters are reduced to the least sonorous element – while extremely common – is not the only possible one. As a matter of fact, Barlow (2001b) herself goes on to discuss the data from a child who consistently reduces /sn/ to [n], in apparent defiance of the universal markedness ranking. Patterns that do not conform to the markedness hierarchy are usually explained through the interference of high-ranked markedness constraints penalizing the candidate that would otherwise be preferred. For instance, Barlow (2001b:302) postulates *COR/#_ , which is violated by word-initial coronal obstruents and therefore prefers the /sn/ → [n] mapping, while Pater & Barlow (2003:495) appeal to *Fricative in a similar situation. The evidence for both *COR/#_ and *Fricative abounds in child phonology. For example, they can be held accountable for the well-known consonant harmony patterns, as in /dak/ → [gak] and stopping processes, i.e., /san/ → [tan], respectively. It has to be noted that while the existence of markedness hierarchies like that illustrated in (1) is well-supported by cross-linguistic evidence outside the realm of child phonology (i.e. the fact that languages with complex onsets often show gaps that can be explained by the sonority distance between the two consonants; Parker 2012), the status of constraints like *COR/#_ is more precarious.

Some studies have pointed out that clusters that escape the sonority-based generalization mentioned above oftentimes have the same shape – that is, they are clusters in which the voiceless sibilant fricative [s] appears as the first element (e.g. Barlow 2001a, b, Goad & Rose 2004). Given the body of knowledge about the peculiar behavior of sC clusters in adult language, it has been proposed that the reasons for the deviant patterning of sC clusters with respect to reduction are due to structural - rather than segmental – reasons (Goad 2011 for an overview). In other words, it has been claimed that sC clusters contain cross-linguistically marked extrasyllabic elements, and it is these elements that are preferentially deleted when cluster reduction applies in child phonology. If this is true, it should be possible to model all – or at least most - attested reduction patterns as the interaction of structural wellformedness constraints with a sonority-based markedness hierarchy. If successful, such an account would be more satisfactory than the alternatives invoking child-specific phonotactic restrictions because it would allow us to uphold the hypothesis of continuity between child and adult phonology – i.e. the idea that developmental grammars are not different in their characteristics from the grammars of attested adult languages.

The main goal of the current study is to ascertain whether – and to what extent – the interaction of traditionally assumed constraints on syllable wellformedness and sonority-based markedness captures the attested reduction patterns in word-initial sC sequences and regular rising-sonority onsets.

The study focuses on cluster reduction patterns exhibited by 20 monolingual Latvian-speaking children, and compares the attested patterns to the factorial typology generated with general constraints derived from insights into the typology of complex onsets in adult languages. The factorial typology is generated with the OT Workplace software (Prince, Tesar & Merchant 2017). Section 2 provides the background on sonority in complex onsets. Section 3 introduces the Latvian data and section 4 provides our analysis, showing how the constraints derived from the typological works discussed in section 2 generate a factorial typology that at the same time overgenerates and, crucially, undergenerates patterns. We show further in section 4 how the assumption of strata partially solves the undergeneration problem. Other patterns that our analysis didn't generate will be explained as structural misanalysis by the children as well as misperception. In section 6 we summarize and conclude.

2 Background: sonority sequencing and syllable phonotactics

The ordering of segments within a syllable is generally assumed to be governed by the Sonority Sequencing Principle (SSP, Selkirk 1984, Clements 1990, Goldsmith 1990 among many others), which states that the sonority of segments rises towards the syllable peak and falls towards syllable margins. The SSP presupposes that all segments are arranged on a sonority scale – the Sonority Hierarchy - from obstruent stops, which are considered to be the least sonorous, to vowels, which are considered to be the most sonorous (Sievers 1881, Jespersen 1904, Kiparsky 1979, Selkirk 1984, Clements 1990, Goldsmith 1990, to name just a few). The Sonority Hierarchy that is traditionally assumed is shown in (2):

(2) Sonority Hierarchy

High vowels > glides > liquids > nasals > fricatives > stops **Low**

The relative harmony of syllables is said to depend on the sonority distance between the element in the margin and that in the nucleus, such that obstruent stops are cross-linguistically preferred in the onset/coda position and vowels make the most well-formed nuclei. The markedness hierarchy for margin elements is given in (3), where numbers indicate a sonority rank.

(3) Relative wellformedness of margins

Stop >	Fricative >	Nasal >	Liquid >	Glide >	Vowel
1	2	3	4	5	6

Similarly, the well-formedness of an onset cluster is determined by the sonority distance between its elements: clusters with a steeper rise in sonority are cross-linguistically preferred, as reflected in the (universal) implicational hierarchy illustrated below (Greenberg 1978, Steriade 1982, Selkirk 1984, Levin 1985, Zec 2007):

(4) Sonority Distance in Onset Clusters

Stop + Glide > Stop + Liquid > Stop + Nasal > Stop + Fricative > Stop + Stop

Interestingly, sC clusters often escape the restrictions imposed by the SSP or Sonority distance (SD). This is evidenced by the fact that languages otherwise requiring their onset clusters to rise in sonority (e.g., English) nevertheless freely admit clusters like [st, sp, sk], where sonority falls towards the syllable peak. Clusters of this type stand out for a number of other reasons as well (see Goad 2011 for an overview and discussion). For instance, they are apparently not affected by the restriction against homorganic tautosyllabic clusters, which is said to account for the ill-formedness of, say, [tl-] in many languages that allow [kl-, pl-] sequences. In addition, some languages that generally don't allow complex onsets may admit word-initial sC clusters (e.g. Acoma, Goad 2011 with a reference to Miller 1965). Conversely, languages that otherwise have complex onsets might ban word-initial sC clusters (e.g., Spanish).

The behaviour of sC clusters in developing grammars is equally puzzling. For instance, it is widely reported that sC clusters as a class differ from other word-initial cluster types in their order of acquisition. However, while several studies have found that sC clusters are acquired before complex onsets (Barlow 1997:135, Yavas et al. 2008 for Germanic) evidence to the contrary also abounds. For instance, Smit et al. (1990) report the results of a large-scale articulation norms study investigating the phonological accuracy of English-speaking children aged between 3;0 and 9;0. Based on the error distribution in their normative sample, they indicate that the recommended ages of acquisition of all sC clusters are 7;0-9;0 years, while ages at which other cluster types are expected to be acquired are 4;0 for [tw, kw], 5;6 for [pl, bl, kl, gl, fl] and 8;0 for two-member clusters containing [r] as a second element (Smit et al. 1990:795).

To account for the seemingly deviant behavior of sC clusters, it has been proposed that [s], rather than being the first element of a branching onset, is affiliated with an appendix – an extra-syllabic constituent licensed by a higher prosodic category (van der Hulst 1984, Goldsmith 1990, see Goad 2011 for an overview and criticism of different approaches). Further, it was proposed (Goad & Rose 2004) that the nature of the licensing category may differ from language to language, and determines the distribution of sC onsets. That is, in languages where appendices are licensed by the prosodic word, tautosyllabic sC clusters may only occur word-initially (by Peripherality Condition, Hayes 1995), while in languages where they are licensed by the syllable, tautosyllabic sC clusters may also occur intervocalically. Another question that has been raised is whether all sC clusters are represented in the same way regardless of their sonority profile, i.e. whether both s + stop and s + sonorant clusters are appendix-initial (Goad 2011). It appears that in some languages s + sonorant clusters, but not s + stop clusters, pattern together with branching onsets (e.g. Urek 2016 for Latvian, van de Weijer 1996 for Gothic, Sanskrit, Modern Standard Hindi), while in others all sC clusters are treated alike (e.g. Steriade 1982 for Attic Greek).

With this background on crosslinguistic onset phonotactics we now turn to the Latvian data.

3 Cluster reduction patterns in Latvian children

In this section, we will first provide information on how the data were obtained. Then we will look at the general picture, break it down by cluster type and finally by subject. In the latter, we look at which combinations of clusters and cluster resolution strategies are found in individual children. This gives us the typology of attested patterns, treating each child pattern as a variety or "dialect" of developing Latvian. This typology is then analyzed in OT in section 4.

3.1 Participants and procedure

The data for this paper come from a norming study of the Latvian Phoneme Test, a picture-based tool aimed at investigating accuracy of phonological production in monolingual Latvian-speaking preschoolers (LPT, Urek et al. in preparation). The Latvian Phoneme Test includes a set of 87 coloured pictures representing familiar objects and actions, where picture labels are selected to contain all consonants and certain consonant clusters of Latvian in word-initial, intervocalic and (where possible) word-final position.

During the norming study, children were tested individually in a quiet room by two investigators. During the test, a child had to name a picture presented by the investigator, while the second investigator marked the accuracy of her production on the scoring sheet. Where possible, spontaneous one-word utterances were elicited. In cases where a child could not name a picture/ did not produce a target word, delayed imitation was used. All responses were audio-recorded. Since our primary focus is on the systematicity of child-specific reduction patterns, for the purposes of this study we have selected the 20 lowest-scoring children from the normative sample of 500 children (mean age = 47 months, SD = 9.3). The responses of these children were transcribed using broad phonetic transcription, and all attempts at word-initial two-member clusters were extracted for the analysis. The examples of stimuli containing such clusters are given in (1). Note that the number of items per cluster type varies due to the structure of the LPT.

(5) Word-initial cluster types

a.	stop + liquid:	[kru:ze]	*'cup',*	[kleita]	*'dress'*
b.	stop + nasal:	[kna:bis]	*'beak'*		
c.	s + liquid:	[sluota]	*'broom',*	[sle:dz]	*'(he/she) closes'*[1]
d.	s + nasal:	[snieks]	*'snow',*	[smejas]	*'(he/she) laughs'*
e.	s + stop:	[spainis]	*'bucket',*	[stu:re]	*'steering wheel'*

[1] Note that s + rhotic clusters are illicit in Latvian.

All child responses were then coded to reflect the production of the attempted cluster. Examples of codes and corresponding child-specific patterns are illustrated in (6):

(6) Child-specific response patterns:

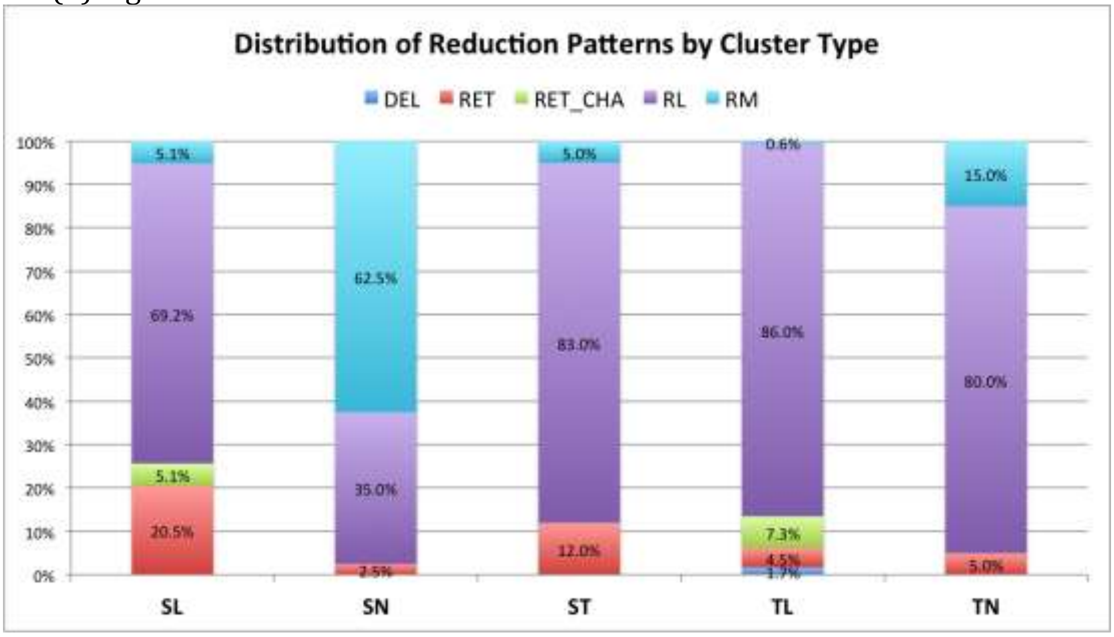
	Pattern	*UR*		*SR*	
a.	fully correct:	/sluota/	→	[sluota]	*'broom'*
b.	fully omitted:	/gredzens/	→	[edents]	*'ring'*
c.	retained with segmental changes:	/kru:ze/	→	[klu:ze]	*'cup'*
d.	reduced to the less sonorous segment:	/blu:ze/	→	[bu:de]	*'blouse'*
e.	reduced to the more sonorous segment:	/snieks/	→	[nieks]	*'snow'*

In the following subsection, the productions of the 20 selected children are discussed by cluster type.

3.2 Cluster types and reduction strategies

Let us first examine the strategies that children in our sample employ to deal with clusters of different types. As can be seen in Figure 1, mean accuracy of production (red segments) is very low and varies considerably by cluster type. Children in our sample demonstrate the highest accuracy on [sl-] clusters (20.5% accurate), followed by s + stop sequences (12% accurate). The proportion of correct productions for other cluster types is at 5% or below. The distribution of accuracy scores in sC clusters agrees with the tendency observed in Yavas et al. (2008:427) for Dutch and Norwegian, who also found [sl-] clusters to be the least problematic, followed by s + stop and s + nasal sequences. Overall, it appears that in Latvian word-initial sC sequences are acquired before onset clusters of other types (which is the reverse of what has been reported in Yavas et al. 2008:430 for Dutch and Norwegian).

(7) Figure 1[2]



The prevalent strategy for cluster resolution is the reduction to the least sonorous element (purple segments), which is not surprising in the light of the previously reported data (sonority pattern, Fikkert 1994, Gnanadesikan 1995, Gierut 1999, Pater & Barlow 2003 among others). The only exception to this general tendency are s + nasal clusters, where the more sonorous segment is retained in 62.5% of cases. Again, this is fully consistent with previous findings reported in Yavas et al. (2008:432) for English, Norwegian, Dutch and Hebrew, where s + nasal clusters are preferentially reduced to the nasal, while in s + stop and s + l sequences the less sonorous segment is kept in most cases. The apparent difference between [sl-] and [sn-, sm-] clusters is quite intriguing, because it cannot be captured by either the sonority strategy (by which the less sonorant element should be kept) or the no-appendix strategy (by which C2 should be retained in all sC clusters). When discussing a similar pattern in the productions of Dutch children, Jongstra (2003:115-119) attributes the greater variation in the realization of s + nasal clusters to the smaller sonority distance between the cluster elements. Jongstra (2003:ibid) argues that the greater the sonority distance between the cluster elements, the more likely a child is to syllabify the cluster as a left-headed branching onset; in turn, the likelihood of appendix-head syllabification is greater in clusters where the sonority distance between the segments is small. Assuming that the head is preferentially preserved in cluster reduction (Goad & Rose 2004), children should be more likely to keep [s] in [sl-] clusters than in [sn-, sm-] – which is exactly what we observe.

While the data summary presented in (7) is useful in that it makes apparent the general tendencies in the data and illustrates the amount of variation in the treatment of different cluster types, it is not at all revealing of phonological competence of individual children, nor does it show the interdependence of the attested reduction

[2] DEL = Both segments deleted; RET = Both segments retained; RET_CHA = segments retained with changes; RL = Reduced to least sonorant segment; RM = Reduced to most sonorant.
S = sibilant fricative; N = nasal stop; T = obstruent stop; L = liquid

strategies in each developmental grammar. At the same time, these individual patterns are crucial for our understanding of how the acquisition of a given structure progresses and whether all attested developmental stages can be accommodated by the existing theories. For this reason, in what follows we discuss child-specific production profiles derived from the same data set and establish a typology of cluster resolution patterns.

3.3 Production profiles, patterns and typology

In order to establish the typology of cluster resolution, a production profile for each participant was generated, showing their production patterns for each cluster type, as illustrated in (8). As you can see, the productions of the child in (8) are somewhat inconsistent, i.e. her treatment of certain clusters varies from item to item (cells containing inconsistent productions are highlighted in yellow). Thus, for example, s + stop clusters are reduced to the stop in four items, and produced faithfully in one item.

(8) Child production profile

		DEL	RET	RET_CHA	RL	RM
LatMon-G-2-4;1						
	SL	0	1	1	0	0
	SN	0	0	0	0	2
	ST	0	1	0	4	0
	TL	0	0	0	9	0
	TN	0	0	0	0	1

Item-to-item variability of productions illustrated in (8) is extremely common in our sample. As a matter of fact, only three children out of 20 are fully consistent in their treatment of different cluster types across all items containing them. This is to be expected, given that variability is highly characteristic of child phonology in general and well-documented both in experimental and in longitudinal diary studies (e.g. Smith 1974, 2010; Yavas et al. 2008, see also Menn et al. 2013 for an overview and discussion).

The question is how one treats variability of this type when faced with a task of creating a formal model of a child´s phonological competence. In the OT literature, several analyses have been proposed to deal with intra-speaker variation (see Cardoso 2008 for an overview and discussion). The approach we adopt here is the one that attributes variability to partial constraint ranking (Boersma 1997, 2008, Demuth 1997, Anttila 1997), i.e. the situation where the dominance relation between two or more constraints is not (yet) fixed. Further, we also assume (following Anttila 1997) that unranked constraints can take any mutual ranking each time a speaker attempts some production, which leads to variable results. A (simplified) example of this is given in (), where the *COMPLEX constraint militating against clusters can either dominate (in a) or be dominated by (in b), the constraint requiring faithfulness to the input. In children, partial constraint ranking is eventually resolved based on the positive evidence from the ambient language.

(9) a. Attempt A: Cluster reduction

/blu:ze/	*Complex	Faith
a. [blu:ze]	*!	
☞b. [bu:ze]		*

b. Attempt B: No reduction

/blu:ze/	Faith	*Complex
☞a. [blu:ze]		*
b. [bu:ze]	*!	

Antilla (1997) proposes that the relative frequency of two variants in adult speech is determined by the number of rankings giving rise to each of the variants. That is, in the toy grammar in (9) the probability of producing the cluster [bl-] faithfully is exactly 0.5 each time it is attempted. This approach, however, is incapable of accounting for the relative frequency of variants in the speech of an individual child. This is because the relative frequency of possible outputs in a child´s productions changes over time: the proportion of non-target-like productions slowly decreases until variability eventually 'fades out'.

To capture the gradualness of learning, it has been proposed that mutual ranking of constraints is probabilistic, and depends on ranking values of individual constraints (Boersma 1997, see also Curtin & Zuraw 2002; see Tessier 2009, Becker & Tessier 2010 for an alternative OT-based account of gradualness). The closer the ranking values of two constraints are, the more likely the mutual ranking of these constraints is to vary. With each erroneous production, the ranking values are slightly adjusted: if the learner´s production mismatches the target, the learner slightly lowers the ranking values of all constraints violated by the target, and slightly raises the values of constraints violated by the learner´s output. As a result, the ranking producing a non-target-like output becomes less and less likely over time. For a child at the variable production stage, we must assume the co-existence of two (or more) possible grammar-states (constraint rankings) that select different optimal outputs for a given input which might also differ with respect to their relative likelihood.

These theoretical considerations determined the treatment of intra-speaker variation in our data. If one of the patterns exhibited by a given child with respect to a given cluster type was prevalent (e.g., if the child reduced the s + stop cluster in four items, and retained it in one), we assumed that the prevalent pattern best reflects the current state of the child´s grammar. In such cases, the 'minor' pattern was disregarded. If patterns exhibited by a given child with respect to some cluster type were equally frequent (e.g., the s + nasal cluster reduced to the nasal in one item and to the fricative in another item), we assumed the existence of two (or more) equally likely rankings, and included both patterns into the analysis. Children who randomly varied on more than one cluster type (N = 2) were excluded from the further analysis. Thus, 18 children gave us 26 production profiles. Of these, 9 followed Pattern 1 (illustrated in (a)), 6 followed Pattern 2 (illustrated in (b)), and the remaining 9 were unique.

(10) Child-specific cluster reduction patterns

a. Pattern 1

	UR		SR	
SL	/sle:dz/	→	[se:dz]	'(he/she) closes'
SN	/snieks/	→	[nieks]	'snow'
ST	/spainis/	→	[painis]	'bucket'
TL	/blu:ze/	→	[bu:ze]	'blouse'
TN	/kna:bis/	→	[ka:bis]	'beak'

b. Pattern 2

	UR		SR	
SL	/sle:dz/	→	[se:dz]	‘(he/she) closes’
SN	/snieks/	→	[sieks]	‘snow’
ST	/spainis/	→	[painis]	‘bucket’
TL	/blu:ze/	→	[bu:ze]	‘blouse’
TN	/kna:bis/	→	[ka:bis]	‘beak’

In (10) above, Pattern 2 illustrates the sonority-based reduction strategy – that is, the less sonorous element is retained across all cluster types. Pattern 1 is a variation of the sonority-based strategy, where s + nasal clusters are reduced to the sonorant. Given the cross-sectional nature of our study, it is not clear whether Pattern 1 and Pattern 2 represent different stages of phonological acquisition (as, for instance, Barlow 2001b found in her longitudinal data) or are alternative developmental paths.

The table in (11) summarizes the eleven patterns that we have observed in our dataset: the topmost row contains inputs (cluster types), while numbered rows represent patterns and contain outputs for each given input.

(11) Attested typology of cluster reduction patterns

	/SL/	/SN/	/ST/	/TN/	/TL/
1.	S	N	T	T	T
2.	S	S	T	T	T
3.	SL	S	T	T	T
4.	SL	N	T	T	TL
5.	L	N	T	T	TL
6.	SL	SN	ST	T	T
7.	S	SN	ST	T	T
8.	S	N	T	N	T
9.	L	N	T	N	TL
10.	SL	N	T	N	T
11.	S	S	S	T	T

As evident from (11), no child in our sample has yet attained full accuracy of production on all cluster types. However, pattern 6 is characterized by accurate productions on all sC clusters and reduction of all branching onsets, which corresponds to Stage IIa in the typology proposed by Barlow (2001a). If we consider patterns where only one cluster type is produced correctly, we will notice a considerable amount of variation. Thus, patterns 5 and 9 only have complex onset clusters with a steep sonority rise (stop + liquid), which could be a version of Stage IIb. Patterns 3 and 10 represent a stage where the only cluster produced correctly is [sl-]. Patterns 4 and 7 are those that allow two cluster types. While in 4 the choice of permitted clusters is clearly determined by the sonority distance between the cluster elements, pattern 7 might be the result of a grammar that allows appendices but not branching structures and where [sl-] is prosodified as a left-headed onset (in line with Jongstra 2003). The remaining patterns in 8 and 11 are those characterized by across-the-board cluster reduction. In 8, the reduction of SN and TN to the nasal can again be attributed to the head mis-assignment (Jongstra 2003, Goad & Rose 2004). Pattern 11 is, perhaps, the most curious of the twelve, as here all clusters are reduced to C_1 regardless of its relative sonority or prosodic affiliation. In what follows, we provide the analysis of the patterns listed in () couched within Optimality Theory.

4 Analysis

In this section we invoke only OT constraints that have been proposed elsewhere in the literature on complex onsets and syllable phonotactics in general. For the sake of clarity and consistency we give all definitions following the template proposed in McCarthy (2008). We will generate the factorial typology of these constraints with OT Workplace and then compare this with the attested patterns in our data.

4.1 Constraints

Since, as discussed above, some languages don't allow appendices while displaying complex onsets, there is reason to assume a constraint against such structures, as given in (). This must be freely rankable with respect to Faithfulness constraints and the markedness constraint against complex onsets, which is familiar from OT textbooks (e.g., Kager 1999) and given below:

(12)
*APPENDIX: 'Assign a violation mark for every appendix.' (Barlow 2001b, Sherer 1994 among others)

(13)
*COMPLEX. 'Assign one violation mark for every branching onset.'

Regarding the wellformedness of onsets, we adopt Prince & Smolensky's (1993/2004:148) approach, in which they claim that lower sonority is more harmonic in onsets and derive a set of markedness constraints from the sonority hierarchy, following the schema in (14). We will, however, depart from their analysis in two crucial ways, the violation profile of these constraints and their intrinsic ordering, as will be explained further below.

(14)
*M/λ - Assign a violation mark for each λ that is parsed as a syllable Margin (i.e. associated to Onset or Coda)

*M/λ constraints are arranged in a fixed dominance order that translates into the implicational hierarchy in (15), as shown below (Prince & Smolensky 1993:148):

(15) *M/a >> *M/i >> ... >> *M/t

Crucially, the *raison d'être* of the fixed markedness hierarchy in (15) is to capture the observation that larger sonority distances between the margins and the peak are cross-linguistically preferred. An important question to ask at this point is how onset clusters are evaluated by *M/λ constraints (here and further we are standardly assuming rankable *COMPLEX, cf. Prince & Smolensky 1993:96). By the definition in (14), [fl-], for instance, will receive a violation mark on *M/f and another one on *M/l (this is the approach adopted by Barlow 1997:63, for example). It is, however, not immediately straightforward why C_1 should contribute to the markedness of an onset cluster if it is not adjacent to the peak or why C_2 should contribute to the markedness of the margin if it is not at the margin. Another problem becomes apparent when sonority-based scales for singleton onsets and onset clusters are juxtaposed, as in (16) (see footnote 1 for abbreviations other than G which represents glides).

(16) Relative markedness of onsets

	T	S	N	L	G	
Less marked	←				→	More marked
	TG	TL	TN	TS	TT	

If *M/λ constraints are allowed to apply to complex onsets, they would prefer TT clusters (only violating the lowest-ranked *M/t) over TG, which violates *M/glide. Thus – assuming rankable *COMPLEX and rankable *M/λ - we predict the existence of languages that only allow stop + stop onsets, languages that allow stop + stop and stop + fricative etc., that is, essentially the reverse of the attested implicational hierarchy. Note that the existence of a separate markedness constraint hierarchy evaluating the sonority distance in onset clusters does not rule out these pathological patterns – as long as the two fixed hierarchies can be freely ranked with respect to each other. Quite obviously, the situation is not remedied if *M/λ evaluates the pre-nuclear element of the cluster only. The tableaux in (17) illustrate the problem:

(17)

/TL-/	*M/l	MAX	*M/f	*M/t	*TT	*TF	*Complex	*TL
a. [TL-]	*!						*	*
b. [L-]	*!							
☞c. [T-]		*!						
/TF-/								
☞a. [TF-]			*	*		*	*	
b. [F-]		*!	*					
c. [T-]		*!		*				

To avoid the pathological scenario illustrated in (18), we re-formulate positional markedness constraints of the type *M/λ in such a way that they don't punish complex onsets for containing a high sonority segment in addition to a low sonority one. In addition, rather than assuming an in-built ranking bias (i.e. a fixed hierarchy) we use a set of stringent constraints (Prince 1997, 1998, de Lacy 2006).

(18)

*L: 'Assign one violation mark for every onset that contains no segment lower in sonority than a liquid.'

*L/N: ‘Assign one violation mark for every onset that contains no segment lower in sonority than a nasal’

*L/N/S: ‘Assign one violation mark for every onset that contains no segment lower in sonority than a fricative’

Note that T is the least marked class in this position. Following Gouskowa (2003) we do not include a constraint against this category. In order to capture the fact that complex onsets typically observe a certain minimal sonority distance which varies from language to language, we adopt a set of stringent markedness constraints of the shape *CC < n that penalize clusters where the distance between the elements is less than some n (along the lines of Wiltshire & Maranzana 1999):

(19)

*CC < 1 : ‘Assign a violation mark for every cluster in which the sonority distance between the elements is less than 1.’ (*TT)

*CC < 2 : ‘Assign a violation mark for every cluster in which the sonority distance between the elements is less than 2.’ (*TF)

*CC < 3 : ‘Assign a violation mark for every cluster in which the sonority distance between the elements is less than 3.’ (*TN)

*CC < 4 : ‘Assign a violation mark for every cluster in which the sonority distance between the elements is less than 4.’ (*TL)

In addition, we adopt faithfulness constraints against deletion of segments. The more specific anti-deletion constraint is restricted to initial position. See, e.g., Beckman’s (1997 et seq.) work on positional faithfulness.

(20)

MAX: ‘Assign a violation mark for every segment in the input that does not have a correspondent in the output.’

MAX-Initial: ‘Assign a violation mark for every segment at the left edge that does not have a correspondent in the output.’

This completes the overview of relevant constraints on onset phonotactics and we move on to discussing their interaction and how it matches our data.

4.2 Ranking

To make the factorial typology manageable we do not consider other candidates than faithful candidates with different options for prosodification and candidates that are missing either the first or second consonant of the cluster in the input. While our children do not epenthesise vowels to avoid complex onsets, a strategy that is widely attested in loanword phonology, other options are attested, such as coalescence, or at least forms that we suspect to display the result of coalescence. We will briefly discuss these options later.

The tableau below illustrates how these constraints account for the sonority-based reduction pattern (or Pattern 2), where a hyphen indicates that a segment is syllabified as an appendix (*CC < n constraints are ranked below *Complex at this stage and not shown here). In (), the mutual ranking of *Complex and *Appendix is irrelevant, because none of these constraints are violated by the winning candidate. The dominance relation between *L, *L/N and *L/N/S similarly does not play a role in the evaluation as long as all of them dominate Max, because for every constraint violated by the winner there will be one violated by its competitor. As you can see, all markedness constraints in (21) dominate all faithfulness constraints, which means that (21) can be taken to represent an early stage of acquisition (if we assume the Initial State hypothesis – Tesar & Smolensky 2000).

(21)

	*Cplx	*App	*L	*L/N	*L/N/S	Max-Init	Max
I. /SL/							
a. [SL]	*!						
b. [S-L]		*!	*	*	*		
☞ c. [S]					*		*
☠ d. [L]			*!	*	*	*	*
II. /SN/							
a. [SN]	*!						
b. [S-N]		*!		*	*		
☞ c. [S]					*		*
☠ d. [N]				*!	*	*	*
III. /ST/							
a. [ST]	*!						
b. [S-T]		*!					
c. [S]					*!		*
☞ d. [T]						*	*
IV. /TL/							
a. [TL]	*!						
☞ b. [T]							*
☠ c. [L]			*!	*	*	*	*
d. [T-L]		*!	*	*	*		
V. /TN/							
a. [TN]	*!						
☞ b. [T]							*
☠ c. [N]				*!	*	*	*
d. [T-N]		*!		*	*		

In (21), all candidates without reduction fatally violate one of the high-ranked constraints against marked prosodic structure. The crucial competition, therefore, is always between the candidates where either C_1 or C_2 has been deleted. In I and II, the candidates in d – i.e., those where a sonorant C_2 is retained - are dispreferred by onset markedness constraints, and as a result the candidates in c – i.e., those where the cluster is reduced to the sibilant – are selected as optimal. Note that the losing candidates are harmonically bounded in both cases, that is, no ranking exists that would render them optimal. This is because the violations incurred by the candidates in d are a superset of violations incurred by the candidates in c. In III, the situation is slightly different. Here, the candidate with C_1-reduction is preferred by *L/N/S. In IV and V, the situation is almost identical to that in I and II. Here, the candidates in (c) – those with retained sonorant C_2 – are harmonically bounded by the winner in (b).

The fact that the candidates with the retained sonorant are harmonically bounded in I and II is obviously problematic for our typology illustrated in (), because it predicts that patterns in 1, 4, 5, 8, 9 and 10 should not be attestable[3]. At the same time, it is intuitively clear that the /sn/ → [n] reduction pattern applies to avoid a marked appendixal constituent, while at the same time preserving the segment syllabified in the onset. However, since inputs in () lack prosodic structure, this intuition cannot be formally expressed. On the other hand, if we assume that inputs in () are fully syllabified, the reduction to C_2 in /sC/ clusters can be conceptualized as appendix deletion.

It has often been suggested that segmental operations apply to prosodified forms, although technical implementations differ (e.g. Jesney 2009). In what follows, we assume that phonology is stratal (following Bermúdez-Otero 2003, 2011, 2012) and therefore that children´s productions are the output of the lowermost – phrase-level – stratum. The input to each stratum below stem-level is the output of the preceding one, and is, therefore, fully prosodified. We further assume that syllabification of forms in higher strata is target-like, such that sC sequences are prosodified as appendix-initial, while other word-initial clusters are parsed as complex onsets. This allows us to capture /sn/ → [n] reduction as the appendix erasure. In turn, /sn/ → [s] can be modelled as a sonority-driven reduction where the appendix element is re-syllabified as a singleton onset. In this case, the crucial choice between the two patterns would depend on the mutual ranking of sonority-based markedness constraints and IDENT-σ, a faithfulness constraint militating against changes in the underlying syllable structure:

(22)

IDENT-σ: Assign a violation mark for every instance where an input segment x_i is associated with some prosodic constituent P and its output correspondent x_o is not associated with P.

---

[3] Pater & Barlow (2003:495), when discussing a similar problem, propose that the attested /SN/ → [N] and /SL/ → [L] mappings are due to the constraint *Fricative. The crucial premise of their analysis is that the deletion of /s/ in clusters is the result of the avoidance of complex structures on the one hand, and dispreference for the fricatives on the other. However, the analysis fails to account for languages like Spanish, which repairs word-initial sC clusters by epenthesis while permitting other types of two-member onsets (including, crucially, fricative-initial sequences). Intuitively, the resolution of sC clusters by epenthesis in adult Spanish is motivated by a structural, rather than segmental, violation.

Note that, like all Identity constraints, IDENT-σ is vacuously satisfied in cases where a segment does not have an output correspondent. That is, the /TL/→ [L] map would not incur a violation of IDENT-σ, because /T/ does not have an output correspondent, and surface [L] is affiliated with an onset.

Given the ranking of *COMPLEX and *APPENDIX above IDENT-σ, and IDENT-σ above *L, *L/N and *L/N/S, candidates in which the sC cluster is reduced to the onset will be preferred. If IDENT-σ is demoted below markedness, as in the ranking with *COMPLEX and *APPENDIX above *L, *L/N, *L/N/S, and the latter above IDENT-σ, sonority-based selection would apply instead, and the /sn/ → [s] map would be chosen as optimal. The tableau in (23) illustrates how IDENT-σ and input syllabification resolve the problem identified in (23).

(23)

	*Complex	*Appendix	Ident- σ	*L	*L/N	*L/N/S	*CC<n	MAX-Initial	MAX
I. /S-L/									
a. [SL]	*!		*				*		
b. [S-L]		*!		*	*	*			
c. [S]			*!			*			*
☞d. [L]				*	*	*		*	*
II. /S-N/									
a. [SN]	*!		*				*		
b. [S-N]		*!			*	*			
c. [S]			*!			*			*
☞d. [N]					*	*		*	*
III. /S-T/									
a. [ST]	*!		*				*		
b. [S-T]		*!							
c. [S]			*!			*			*
☞d. [T]								*	*

In (23), there are no candidates that are harmonically bounded, which means that every shown output candidate can in principle be chosen as optimal for a given input by some constraint ranking. In I and II, candidates in (a) and (b) are penalized by constraints against marked syllable structure, while candidates in (c) crucially violate IDENT-σ. As a result, candidates in (d) are correctly selected as optimal. In III, the situation is essentially identical. The only difference is that the winner in (d) is also more harmonic than its competitor in (c) on sonority-based markedness constraints that prefer plosive onsets to sibilant ones. Therefore, with *COMPLEX and *APPENDIX both ranking high, the optimal output for /S-T/ would depend on the ranking of MAX-Initial relative to IDENT-σ and *L/N/S.

In the following section, we discuss the factorial typology derived from these constraints.

4.3 Factorial Typology

The factorial typology generated by OT Workplace for the constraints in (23) contains 48 possible surface languages shown in (24)-(28) (while the number of all logically possible reduction patterns is 1024). Importantly, each surface language might be the result of more than one total constraint ranking (we will return to this point below). Languages that correspond to the patterns attested in our sample are shown in (24). Note that in our child data it is impossible to distinguish between e.g. [s-n] and [sn-]. For this reason, all patterns that segmentally correspond to our attested ones have been selected.

(24) Attested patterns

	/S-L/	/S-N/	/S-T/	/TL-/	/TN-/
Lg#3	SL	SN	ST	T	T
Lg#6	SL	SN	S-T	T	T
Lg#16	SL	S-N	S-T	T	T
Lg#25	SL	S	T	T	T
Lg#27	SL	N	T	TL	T
Lg#33	S-L	S-N	S-T	T	T
Lg#37	S	S-N	S-T	T	T
Lg#41	S	S	S	T	T
Lg#43	S	S	T	T	T
Lg#45	S	N	T	T	T
Lg#47	L	N	T	TL	T

The table in (25) lists all the patterns that segmentally correspond to adult Latvian. Note that our typology predicts seven possible syllabifications of initial sequences. Language 1 is the language where all sequences are syllabified as complex onsets, while Language 32 is the one where they all contain an appendixal element. The syllabification of other sequences follows markedness hierarchy for clusters that follows from the constraints in (19).

(25) Segmentally target-like patterns

	/S-L/	/S-N/	/S-T/	/TL-/	/TN-/
Lg#1	SL	SN	ST	TL	TN
Lg#4	SL	SN	S-T	TL	TN
Lg#13	SL	S-N	S-T	TL	TN
Lg#14	SL	S-N	S-T	TL	T-N
Lg#29	S-L	S-N	S-T	TL	TN
Lg#30	S-L	S-N	S-T	TL	T-N
Lg#32	S-L	S-N	S-T	T-L	T-N

Let us now turn to the discussion of the patterns overgenerated by our analysis. The table in (26) lists all the predicted languages that have both types of stop-initial complex onsets.

(26) Overgenerated patterns: languages with two types of complex onsets

	/S-L/	/S-N/	/S-T/	/TL-/	/TN-/

Lg#7	SL	SN	S	TL	TN
Lg#10	SL	SN	T	TL	TN
Lg#17	SL	S	S-T	TL	TN
Lg#20	SL	S	S	TL	TN
Lg#23	SL	S	T	TL	TN
Lg#26	SL	N	T	TL	TN
Lg#46	L	N	T	TL	TN

As you can see, the languages in (26) differ with respect to which type of sC clusters they allow. In Lg#46, all s-initial clusters are banned. This language corresponds to Stage IIb in the typology of cluster reduction patterns identified by Barlow (2001a), and represents a classic "no-appendices" developmental pattern. Languages 20, 23 and 26 each allow only one sC cluster, and for all of them it is SL – that is, the sC sequence with the steepest sonority rise. Note that the languages differ with respect to the reduction strategy employed in other sC sequences: in Lg#26, the appendices are erased, Lg#23 follows the sonority pattern in keeping the least sonorous member of the sequence, while in Lg#20 the initial member of the sequence is kept in conformity with MAX-Initial. Languages #7 and #10 are the ones where the sC inventory is expanded. Unsurprisingly, the expansion follows the sonority-based cluster wellformedness principle, and the next sC sequence to be added is SN. The most curious pattern is Lg#17, in which all three types of sC sequences are treated differently.

The table in (27) lists all languages in which only one stop-initial cluster type is allowed. Notice that in all cases that cluster is of the type TL, which is in conformity with typological observations. Notice also that in all cases TN is reduced to the stop – which is to be expected based on the positional sonority-driven markedness for singleton onsets.

(27)

	/S-L/	/S-N/	/S-T/	/TL-/	/TN-/
Lg#2	SL	SN	ST	TL	T
Lg#5	SL	SN	S-T	TL	T
Lg#8	SL	SN	S	TL	T
Lg#11	SL	SN	T	TL	T
Lg#15	SL	S-N	S-T	TL	T
Lg#18	SL	S	S-T	TL	T
Lg#21	SL	S	S	TL	T
Lg#24	SL	S	T	TL	T
Lg#31	S-L	S-N	S-T	TL	T
Lg#34	S	S-N	S-T	TL	T-N
Lg#35	S	S-N	S-T	TL	T
Lg#38	S	S	S-T	TL	T
Lg#40	S	S	S	TL	T
Lg#42	S	S	T	TL	T
Lg#44	S	N	T	TL	T

Again, the languages in (27) differ in their treatment of sC sequences. Lg #40, 42 and 44 are those where all sC sequences are reduced. Of these, #40 apparently complies with MAX-Initial, while Lg#42 follows the sonority pattern. Lg#44 is curious in that it treats SL and SN clusters differently. However, Lg#44 is reminiscent of Pattern 8 attested in our data, where the reduction pattern on sC clusters was exactly the same. Languages 2, 5, 15, and 31 are those where all sC sequences get to surface. The differences between them lie in the syllabification of different types of s-initial clusters. Language #2 stands out in that it bans TN but allows a more marked ST as a complex onset. In our typology, the pattern arises as a result of highly-ranked MAX-Initial that prevents the reduction of /s-t/ to [t] and *L/N/S that rules out /s-t/ to [s]. Languages 5, 15 and 31 only differ with respect to the "sonority threshold" at which /s/ is expelled to the appendix position – again, this follows the sonority hierarchy. In languages with only one sC cluster (18, 21, 24), it is, predictably, SL, while languages with two sC clusters (8, 11) expand the inventory with SN - and this pattern is kept throughout our typology. Finally, in Lg#34, Lg#35 and Lg#38 the prosodic status of C_1 depends on the relative sonority of the following segment.

Finally, let us discuss the languages in which no stop-initial onset clusters are allowed. Language 48, where all sC sequences are reduced to C_2 and stop-initial sequences are reduced to C_1 corresponds to the widely attested "head pattern" (see Goad & Rose 2004). Languages which parse sC sequences as onsets (9, 12, 19, 22, 28) are in conformity with sonority distance considerations. In languages that admit appendices (36, 39), the relative sonority of C_2 plays a crucial role.

(28)

	/S-L/	**/S-N/**	**/S-T/**	**/TL-/**	**/TN-/**
Lg#9	SL	SN	S	T	T
Lg#12	SL	SN	T	T	T
Lg#19	SL	S	S-T	T	T
Lg#22	SL	S	S	T	T
Lg#28	SL	N	T	T	T
Lg#36	S	S-N	S-T	T	T-N
Lg#39	S	S	S-T	T	T
Lg#48	L	N	T	T	T

Finally, we should discuss the patterns that have been attested in our data but are predicted to be impossible by our typology. For the sake of convenience, these are repeated in (28):

(29)

	/S-L/	/S-N/	/S-T/	/TN/	/TL/
8.	S	N	T	N	T
9.	L	N	T	N	TL
10.	SL	N	T	N	T

It goes without saying that, given the small number of children we have data from, undergeneration is a more serious problem for a typology than overgeneration is, and therefore the reasons leading to this problem need to be carefully considered. As is clear from (), all undergenerated grammars are the ones where the /TN/ cluster is reduced to [N]. Undergeneration of these patterns results from the candidate with the map /tn-/ → [n] being harmonically bounded by the competitor which maps the underlying cluster onto a voiceless stop. Unlike in the case with /s-l/→ [s], the problem cannot be resolved by IDENT-σ, because neither map incurs a violation of it.

(30)

	*COMPLEX	*APPENDIX	IDENT-σ	*L	*L/N	*L/N/S	MAX-	MAX
I. /TL-/								
a. [TL-]	*!							
☞b. [T-]								L
☠c. [L-]				W	W	W	W	W
d. [T-L]		*!	*	*	*	*		
II. /TN-/								
a. [TN-]	*!							
☞b. [T-]								L
☠c. [N-]					W	W	W	W
d. [T-N]		*!	*		*	*		

Patterns with reduction of initial clusters other than sC to the more sonorous element are quite rare, and often either not discussed in the theoretical literature at all or implicitly assumed to be unattestable (Pater & Barlow 2004, Goad & Rose 2004). There is, however, a number of documented cases of the map /STOP+SON/ → [SON] in child speech. For example, Jongstra (2003:113) reports that children in his sample differed in their treatment of the initial /kn-/, and both [k-] and [n-] variants were attested. Furthermore, based on his data, Jongstra (2003:ibid) proposes the implicational hierarchy, “if /kn/ is realised as [n], then /sn/ is realised as [n], and /sm/ is realised as [m], but not vice versa”. This implication is preserved in our data as well (see ()). Jongstra (2003:116) attributes the between-child variability in the treatment of /kn/ to the head mis-assignment resulting from the two elements being similar to each other in terms of sonority (refer to Goad & Rose 2004 for the discussion of the headedness-based cluster reduction pattern). That is, some children might erroneously identify /k/ as an appendix, and then subsequently delete it. The tableau below shows that assuming an input with TN syllabified as an appendix-onset sequence resolves the problem of undergeneration in our typology.

(31)

	*COMPLEX	*APPENDIX	IDENT-σ	*L	*L/N	*L/N/S	MAX-Initial	MAX
/T-N-/								
a. [TN-]	*!							
b. [T-]			*!					*
☞c. [N-]					*	*	*	*
d. [T-N]		*!	*		*	*		

An alternative solution to the problem could be to include the constraint CONTIGUITY (McCarthy & Prince 1995), which punishes string-internal deletion. The tableau below illustrates the effect of this constraint on the candidate selection in case of input /TN-/:

(32)

	*COMPLEX	*APPENDIX	CONTIGUITY	IDENT-σ	*L	*L/N	*L/N/S	MAX-Initial	MAX
/TN-/									
a. [TN-]	*!								
b. [T-]			*!						*
☞c. [N-]						*	*	*	*
d. [T-N]		*!		*		*	*		

In (32) above, candidate (b), where the second element of the cluster has been deleted, fatally violates the CONTIGUITY constraint, and so candidate (c) is selected as optimal. Note that CONTIGUITY also prefers reduction to the sonorant for the input /TL-/, and therefore predicts the mapping that has not been attested in our data.

Another potential explanation for C_1 deletion in target [TN-] sequences is the influence of acoustic factors. For instance, Davidson & Shaw (2012) conducted a perceptual confusion study, in which English listeners had to discriminate pairs of nonce words, where one word contained a non-native initial cluster, and the other – some modification thereof (e.g. [tmafa]/[mafa], tmafa]/[ətmafa], etc.). They found that C_1 deletion modification could be discriminated only in 64% of trials, which means that in other cases a participant did not perceive the difference between the word-initial stop+nasal cluster and a singleton nasal onset. Davidson & Shaw (2012) attribute the results to the fact that stops have low intensity bursts before nasals, which makes C_1 in stop + nasal clusters less acoustically salient. Even though the [kn-] onset is licit in Latvian, it is possible that some LPT participants misperceived [kn-] as [n], and therefore did not have the stop in the underlying representation to start with.

5 Conclusions

In this paper, we contribute to the understanding of cluster resolution in child language. The Latvian data we presented pose some challenges to previous analyses of similar child patterns. To account for the typology that results from looking at individual patterns we had to take seriously the distinction between appendix + onset and complex onsets. As we argued in the previous paragraphs, an account that doesn't consider this structural difference fails on principled and empirical grounds. Furthermore, this distinction also led to the insight that, at a deeper level, the children we reported on here manage to parse clusters correctly. It is only at a later level of grammar that structures are simplified. We thus capture the insight that the children avoid appendixes by deleting the appendix, which can't be formalized in a fully parallelist mono-stratal version of OT.

As a side effect, reflection on the nature of wellformedness constraints on onsets resulted in a redefinition of these constraints, since, with the definition used in large parts of the literature, they lead to unwarranted typological predictions, such as languages that allow only complex onsets with sonority plateaux.

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