3 Early Phonology: The Shapes of Syllables

3.1 Preliminaries

This chapter begins the analysis of child phonology in earnest, where you will begin to describe and even explain the grammatical systems that children use to pronounce words. First we have some preliminaries to get in place: for example, we have to decide when a child's speech production begins to involve a phonology.

3.1.1 When Does Phonology Begin?

As a conceptual definition, we might say that a child is using a phonological grammar once they have a stable, core set of pronunciations for lexical items, which is more or less generalized to new items as well. But how can we use that definition in the real world? Unsurprisingly, opinion is mixed as to how systematic a child's productions need to be. The most common such method is to pick a minimum number of words in the child's vocabulary, as it is often claimed that stability and predictability in phonological production emerges when children cross a particular lexical threshold somewhere between 50 and 200 words (for overview and discussion, see Sosa and Stoel-Gammon, 2006; Zamuner, 2009; cf. Vihman and Velleman, 1989; Vihman and McCune, 1994).

Regardless of the criteria used, the earliest phonological outputs often show a considerable degree of variability, and analysts must decide to what extent the variation is a property of a child's grammar, or extra-grammatical factors, or something in between. After we have seen many data sets, Chapter 5.7 will return to these questions of variation in earnest. But to begin, the next few chapters will seek to look past this variation, and find some broader generalizations lurking beneath.

3.1.2 Where Does the Child Get their Inputs?

We must also make some initial guesses as to the representations involved in a child's phonological mappings: that is what are their inputs and outputs?

Since we have the outputs more or less available on the surface, the crucial problem is the correct input, and here Chapter 2's results will be our initial guide. There we learned that by their first birthday, children can perceive (most) native language contrasts adequately; thus we will assume that they have (most) target outputs accurately in mind, at least when attempting to produce familiar words.

We will therefore work with the assumption that early phonological production proceeds by taking target-like, accurately-produced segmental strings as *inputs*, and then using the child's current grammar to attempt mimicking those inputs in their own *outputs*. However, we will also assume at the outset that children only encode input properties that they can perceive overtly in the ambient language: concretely, this means inputs will contain stress, whose phonetic correlates are salient, but not syllabification. For example, a child's input for the word 'ice cream' will be something like /ˈaɪskɹ̩ɪm/: containing all the target segments, as well as primary stress on the initial diphthong and secondary stress on the second vowel. (These assumptions will need to be revisited many times throughout this text, starting already in Section 3.4.2.)[1]

In comparison to their target-like inputs, of course, a child's early outputs will usually fail to be accurate, since their grammar is not yet target-like – and so the child's grammar will make errors, which it is now high time we studied.

3.2 Syllable Shape Inventories

We begin with some early words in four languages – European Portuguese, Greek, Quebec French and American English – produced by children in their second year (ages 1;2–2;0). Our first focus will be on the contents and shapes of <u>syllables</u> in the children's outputs, and how they differ from their target syllable structures. Skim through the following four data sets, and look first just at the children's outputs (in bold). What syllable structures do they contain?

[1] For summaries of various alternative views of children's underlying representations, see especially Rose and Inkelas (2011): section 4, Jaeger (1997), and also more discussion in Chapters 7.4 and 8. For much more discussion of what it means for the learner to receive 'input' to the learning acquisition procedure, see especially Carroll (2001), which focuses on second language morpho-syntactic acquisition, but is still very helpful in framing the issues.

(1a)

European Portuguese: Freitas (2003)			
Target	*Child*	*Age*	*Gloss*
/ˈkɾɛmɨ/	**[ˈkɛ]**	(1;5.11)	*cream*
/ˈabɾɨ/	**[ˈabi]**	(1;8.2)	*open*
/ˈpɾajɐ/	**[ˈpajɐ]**	(1;10.29)	*beach*
/tɾiˈsiklu/	**[tiˈkiko]**	(1;10.29)	*bicycle*
/lɐˈdɾaɾ/	**[ˈdal]**	(1;5.17)	*to bark*
/ˈgɾɐ̃dɨ/	**[ˈgɐ̃:dɨ]**	(1;11.10)	*big*

(1b)

Greek: Kappa (2002)			
Target	*Child*	*Age*	*Gloss*
/ˈsakis/	**[ˈkaki]**	1;11	(proper name)
/baˈbas/	**[baˈba]**	1;10	*daddy*
/kalˈtson/	**[toˈto]**	1;11.7	*tights*
/fos/	**[po]**	2;0	*light*
/bes/	**[be]**	2;0.7	*come in* (imperative)

(1c)

Quebec French: Rose (2000: 96)			
Target	*Child*	*Age*	*Gloss*
/gasˈpɑʁ/	**[pəˈpæː]**	1;3.07	(proper name)
/ˈɑ̃ˈkɔʁ/	**[kæː]** **[kɔː]**	1;3.08 1;3.23	*again*
/paˈtat/	**[pəˈtæː]**	1;4.07	*potato*
/lwaˈzo/	**[lɑzɔᶷ]**	1;4.07	*the bird*
/ljɔ̃/	**[lɑː]**	1;4.07	*lion*
/sɑ̃nˈdal/	**[θaˈðæ]**	1;4.14	*sandal*
/tuʁˈlu/	**[dʏˈlʊ]**	1;6.22	*bye-bye*
/ˈflœʁ/	**[βœj]**	1;7.27	*flower*
/kχɛˈjɔ̃/	**[keˈjɔ]**	1;7.27	*pencil*

(1d)

English (Trevor: Compton and Streeter, 1977; Pater, 1996)						
target	*Child*	*age*		*target*	*child*	*age*
clock	**[kæ]**	1;2.1		*moon*	**[mu]**	1;3.11
puppet	**[pʌpə]**	1;2.1		*stick*	**[tɪ]**	1;3.11
give	**[gɛ]**	1;2.3		*cracker*	**[kækæ]**	1;3.11
pinecone	**[gaigo]**	1;2,6		*cold*	**[ko]**	1;3.21
vacuum cleaner	**[gakagaka]**	1;2.16		*cup*	**[kʌ]**	1;3.25
shoes	**[ʃu]**	1;2.20		*scissors*	**[ʃɪʃɪ]**	1;3.25
owl	**[aʊː]**	1;2.25		*ice cream*	**[aigi]**	1;3.25
blanket	**[gækɪ]**	1;3.11		*apple*	**[æbo]**	1;4.6

Looking just at the *outputs*, these children all share one predominant surface syllable shape: CV. (In European Portuguese we see one final [l] coda; in Quebec French there are some vowel length differences; nevertheless CV is the overwhelming majority.)

The next question about the grammar is how these CV syllables are being formed: which syllable structures have been lost from the targets? In (1), the targets have been transformed into *inputs* so they have no syllabification (since children can't hear syllables) – but all the segments are there, so recalling the syllabification strategies from Chapter 1 should let you guess the adult syllabifications fairly accurately. To take Trevor's example of *ice cream*: in the adult form, both *ice* and *cream* have a single coda consonant, and *cream* also has an onset cluster; in the child's output, all three are missing:

(2) Different syllabifications, in a mapping from (1d):

Target: /aɪskɹɪm/ → [aɪ**s**.**k**ɹɪ**m**]
Child: /aɪskɹɪm/ → [ai.gi]

So we have two processes: deletion of some onset segments, and all coda segments (small exceptions not included). And both processes can be understood intuitively as aiming for a common syllable target: [CV].

All of the languages being acquired by the children in (1) allow much complicated syllables than [CV] to surface – in that sample of target words, you can find syllables with the shapes [V], [CVC], [CCV], [CCVC] and [CVCC]. But there are indeed adult grammars whose syllable shape inventory looks very similar to (1). For example, here are some representative words from Cayuvava, an extinct language once spoken in Bolivia:

(3)

Cayuvava syllables (Key, 1961)[2]			
[ˈko.rã.βa]	*large black birds*	[haˈtʃo.tʃo.ɛ]	*I love*
[aˈri.bo.ro]	*he already gave it*	[i.ˈa.ru,a]]	*death*
[taʼka.a.si]	*old man*	[tu.iˈdʒi.ɲi.ka]	*on house top*
[ˈki.tɔ.rɛ]	*kind of tick*	[ˈri.mo]	*lemon*

Words in Cayuvava can get quite long, but each syllable is only of two types: CV or V. Similarly restrictive syllable inventories are found in Hawaiian (whose syllables are all CV or CVV) and Hua (which Blevins, 1995 reports as strictly CV). In other words: some target languages share the same syllable inventory as the child grammars in (1).

What is perhaps equally revealing is the *converse* fact – that is that no child or adult phonology looks like (4) below:

(4)

Unattested syllable structure grammar			
Target	*Output*	*Target*	*Output*
/ˈsakis/	[ˈas.is]	/ˈkɾɛmɨ/	[ˈɛ.ɨm]
/fos/	[os]	/tɾiˈsiklu/	[i.ˈik.ol]
/bes/	[es]	/ˈpɾajɐ/	[ˈa.ɐp]

The unattested language in (4) appears to prohibit what (1) allows and allow what (1) prohibits: all syllables are moulded to the shape [VC], with no onset and an obligatory coda. It's not that such reversals don't occur in certain circumstances, but they never appear in an across-the-board flavour like (4).

Taken together, this cross-linguistic evidence from child and adult languages suggests that phonological grammars prefer CV syllables over the alternatives: they are where child phonologies start, and more complex syllable structures are built from them. How to impose these preferences in the grammar?

One option might have been to define CV as the 'optimal syllable', and then describe the initial state of phonological development as allowing only

[2] Details of final vowel devoicing are left out of transcriptions for ease of reading; see also Key (1961: 145 regarding some unstable occasional /gr/ clusters).

the optimal syllable. Thus far, we would then have said that if an input cannot be syllabified only using the optimal syllable, i.e. [CV.(CV).(CV) ...], the phonology will delete input segments until only optimal syllables remain.

This approach turns out to be somewhat unsatisfying, for a number of reasons. Here is one: many children insist that their outputs contain *some* of the optimal syllable's properties, but not all of them. For example, here is another child, G, learning English at around age two:

(5)

G (Gnanadesikan, 1995/2004)				
clean	[kin]		please	[piz]
sleep	[sip]		friend	[fɛn]
slip	[sɪp]		spill	[bɪw]
skin	[gɪn]			

This grammar's output syllables are *somewhat* optimal, but not entirely so. It imposes the restriction of only one onset segment per syllable, but it also tolerates coda consonants. Likewise there are adult languages that impose this slightly more permissive syllable structure – one clear example is Yakuts, illustrated in (6). Notice too in these words that Yakuts does not *require* a syllable to have a coda: the CV syllable is always an option, but now CV(C) is too (onsetless syllables [V(C)] are also permitted).

(6)

Yakuts (cited in Baertsch, 2002: 54, 92)							
[bɪ.raa.bɪ.la]	*rule*		[sap]	*thread*		[e.tiŋ]	*thunder*
[se.re.de]	*Wednesday*		[at]	*horse*		[su.rudʒ[3]]	*to write*
[kin.gie]	*book*		[ba.lik]	*fish*		[im]	*sunset*
[sɪ.ma.la]	*resin, pitch*		[su.lus]	*star*		[dʒil]	*year*

To capture both the very strict CV languages and these more moderate CV(C) languages, we will need something more nuanced than a single optimal syllable. Instead, we need a grammar that makes reference to all the pieces of an optimal syllable – each one describing one desirable property of the syllable, which each language may or may not obey. The property shared

[3] This final segment is an affricate, just as in English *judge [dʒʌdʒ]*, and so counts as a single coda segment.

by all our child outputs thus far has been the one in (7); the one that has been varyingly obeyed is in (8):

(7) NoComplexOnset No onset contains more than one segment
(8) NoCoda No syllable contains a coda

These descriptions of output properties will become one set of OT *constraints*,[4] which grammars can enforce to varying degrees – and while all the target languages in (1) happily disobey these constraints, we will still find use for them along the way.

To round out a bit more of the syllable structure typology, let's look at two other children: one learning English (9) and the other Dutch (10). Before you continue reading, describe in your own words the property of syllable structure that these two children are imposing on their inputs:

(9)

Amahl at 2;7 (Smith, 1973)[5]			
Target	*Child*	*Target*	*Child*
Elastoplast	ˈlaːtəb̥laːt	*pleased*	pliːd
book-shelf	buklɛf	*scales*	g̊eil
box	bɔk	*touched*	tʌt
desk	gɛk	**touched*	tʌʧt
footprint	wutplit	**fact*	wækt

(10)

Dutch (Fikkert 1994: 57-58)			
Target	*Child*		*Gloss*
/ˈoːtoː/	[ˈtaːtoː]	J (1;6.27)	*car*
/ˈaːpiː/	[ˈtaːpiː]	J (1;7.15)	*ape* (dim.)
/ˈoːtoː/	[ˈtoːtoː]	T (1;2.27)	*car*

Continued

[4] It is standard OT practice to write constraint names as all one word and in small caps. All the constraints used in this textbook have been previously proposed in the OT literature, in some format; some of them are borrowed verbatim and some are reworked considerably. In most cases, a new constraint will be introduced along with some key references as to its provenance. If a constraint is so basic or universally used that citation has been abandoned, it can be found in the classic OT references listed at the end of this chapter's further reading.

[5] Note that Amahl's prohibition on complex codas was more segmentally-subtle than this; the full pattern is discussed in Chapter 6.

Target	*Child*		*Gloss*
/aːp/	[baːp]	T (1;3.24)	*ape*
/aːp/	[paːp]	L (1;9.15)	*ape*
/ˈapəl/	[ˈpaːpuː]	L (1;10.29)	*apple*

The data in (9) suggest that this child's grammar does not permit coda clusters with more than one segment (with a couple of starred *exceptions). The Dutch data in (10) shows a different pattern: comparing the inputs and outputs here, it seems that these children's grammars do not permit a syllable to begin without an onset. Thus we need two more constraints:

(11) NoComplexCoda — No coda contains more than one segment
(12) Onset — No syllable lacks an onset

It will now not be surprising that these properties are imposed to varying degrees in other adult languages too – recall Hua's CV-only syllables mentioned above (which requires satisfying Onset) – and the numerous languages that only permit single codas but no coda clusters include Spanish and Cantonese.

We have now begun to describe how a phonological grammar can regulate its syllable structure. The requirements are broken down into a set of local properties, each regulated by a constraint on outputs, and each language decides which ones to obey. To illustrate the options, the following table lists some syllable shapes and their satisfaction or violation of each constraint (try to add other syllables to the table!):

(13)

	NoCoda	Onset	NoComplexOnset	NoComplexCoda
CV	**satisfies**	**satisfies**	**satisfies**	**satisfies**
CVC	*violates*	**satisfies**	**satisfies**	**satisfies**
V	**satisfies**	*violates*	**satisfies**	**satisfies**
VC	*violates*	*violates*	**satisfies**	**satisfies**
CVCC	*violates*	**satisfies**	**satisfies**	*violates*
CCV	**satisfies**	**satisfies**	*violates*	**satisfies**

Note this set of constraints also captures the idea that CV is the optimal syllable. How? Because C violates none of these syllable structure constraints.

A leading idea in the study of syllable structure acquisition is that table (13) not only describes all the properties of child and adult grammars alike, but also that it predicts order of acquisition, so that the more constraints a syllable structure violates, the later it will be acquired. This notion goes back at least to Jakobson (1941) – and we will see many domains where it runs into trouble – but for syllables it has been remarkably accurate. A notable success of this approach comes from 12 Dutch-acquiring children reported in Levelt, Schiller and Levelt (1999) and Levelt and van der Vijver (2004). Below in (14) is a summary chart of the syllable acquisition paths that these Dutch-acquiring children took – and it would seem to show that each successive stage of syllable structure acquisition moved learners from a more restricted, more cross-linguistically preferred set of syllable shapes to a larger set with more options:

(14) Upshot of Dutch syllable acquisition reported in Levelt, Schiller and Levelt (1999)

Stage		1	2	3		4		5		
Syllables Added to Legal Outputs	Path a)	CV	CVC	V	VC	CVCC	VCC	CCV	CCVC	CCVCC
	Path b)					CCV	CCVC	CVCC	VCC	CCVCC

In broad strokes, these developmental paths are pretty typical, moving from simpler to more complicated output syllables. However it is also clear that these paths are influenced by language-specific factors, with various explanations. In the Dutch data above, the two trajectories differ on whether onset or coda clusters are learned first – some kids produced [CCV] before [CVCC] and others did the reverse. In German acquisition, Lleo and Prinz (1996) provide spontaneous production evidence from five children that onset clusters are acquired before coda clusters, as do Demuth and McCullough (2009a) for the acquisition of French. On the other hand, Kirk and Demuth (2003)'s experimental study suggests that for English-learning children the reverse is true, at least in that coda clusters are more accurately produced before onset ones. Similarly, children learning the Dravidian language Telugu spoken in India (Chervela, 1981), and learning Mexican Spanish (Macken, 1978), are reported to produce certain coda clusters before any onset clusters emerge. Thus, language-specific factors must be interacting with other principles to produce specific paths like in (14): more to come.

In terms of chronological age and development, consonant clusters in particular provide a great empirical testing ground: some two-year-olds learning some languages can produce many clusters correctly, while some eight- and nine-year-olds are still struggling with others (for a review and many key references, see McLeod et al., 2001). And as we have already seen, syllable structure typology is fairly well understood across the world's languages, so the comparisons between child and adult patterns are plausibly accurate. Thus, children's stages of syllable structure provide an excellent empirical area in which to build our theory of developing phonological grammars.

3.3 Optimizing Syllable Shapes

The previous section provided some core data demonstrating grammatical preferences for syllable shapes and a set of constraints that can impose these preferences. Before we can go any further, though, we need a working grammar that uses these constraints, to see what we can account for in children's speech.

Suppose we think of structural constraints as filters, which rule out ungrammatical surface outputs. And what does the grammar do when the input fails to obey one of these structural constraints? The previous section's datasets demonstrated that in the earliest cases, children's grammars impose optimal CV syllables via segmental *deletion*. In Trevor's case: when at 1;3 his grammar is given the input /kʌp/ *cup*, it prefers the surface result [kʌ] without a coda compared to the adult version.

We will keep track of these grammatical preferences in a *tableau*, shown in (15). The first row provides the input to the grammar, and the constraints at issue. Each subsequent row of the tableau indicates how many times each potential output for the top row's input violates each constraint, with one asterisk for every violation as defined in (16) below:

(15)

	/kʌp/	NoCoda
a)	[kʌp]	*
☞ b)	[kʌ]	

(16) NoCoda defined:
Assign a violation mark (*) for every syllable in the output that contains a coda

The whimsical ☞ indicates the grammar's preference: since [kʌ] violates this grammar's lone structural constraint fewer times than the other output *candidate* under consideration, it is referred to the *optimal* candidate or output.

In the case of Trevor's pronunciation of *stick*, the grammar prefers more deletion – because we have *two* structural constraints that the input disobeys, and each violation must be repaired. Make sure you can define the structural constraint *COMPLEXONSET in the manner of (16) before reading past this tableau:

(17)

/stɪk/	NOCODA	*COMPLEXONSET
[stɪk]	*!	*!
[stɪ]		*!
[tɪk]	*!	
☞ [tɪ]		

The exclamation points in this tableau are a standard way of highlighting why each suboptimal candidate lost out to the optimal one – that is they show which constraint filtered out that row's losing candidate, in favour of the winning optimal one. Notice that the ordering of the rows in a tableau is arbitrary: each one simply lists a potential candidate and its violations.[6]

By now you may be wondering about target English – that is what is the difference between child and adult English grammars? Why does NOCODA not cause Trevor's parents to also pronounce *cup* as *[kʌ]? It can't be because deletion is something special about children's developing phonologies (or their motor control or planning properties or anything similar) because many adult language phonologies also reduce their dispreferred syllable shapes via deletion. An example from the Polynesian language Samoan is illustrated in (18) below. These Samoan perfective verbs all end with the suffix [-ia]; those in (18b) have a consonant-final stem, but all their simple forms have deleted that consonant, so that on the surface all syllables are (C)V:

(18)

	Samoan syllable structure (data from Harris, 2011)						
a)	*Simple*	*Perfective*	*Gloss*	b)	*Simple*	*Perfective*	*Gloss*
	o.lo	olo.i.a	*rub*		a.pi, *a.pit	api.ti.a	*be lodged*
	a.ŋa	aŋa.i.a	*face*		so.po, *so.poʔ	so.po.ʔi.a	*go across*
	tau	tau.i.a	*repay*		mi.lo, *mi.los	mi.lo.si.a	*twist*
					o.so, *o.sof	o.so.fi.a	*jump*
					tau, *taul	tau.li.a	*cost*

[6] The questions of how output candidates are created (from an input or elsewhere), and what the order of the columns means, will get addressed as the chapter continues. Keep reading …

Why isn't the simple verb meaning 'be lodged' pronounced *[a.pit]? Because Samoan doesn't tolerate violations of the constraint NoCoda any more than Trevor does.

A very different example comes from prefixing *reduplication* in Tonkawa (a language isolate once spoken in Oklahoma and Texas). All of the verbs in (19) begin with a complex syllable – containing a long vowel VV and some cases an additional coda VVC – but when reduplicated these are both deleted and shortened to CV.[7] (If 'reduplication' is a completely novel term to you, just compare the underlined syllable shapes in the reduplicated forms to their ungrammatical forms, marked with a *, and notice that the former contain only CV syllables. Reduplication will be explained in earnest in Chapter 4.)

(19)

	Tonkawa (data from Gouskova, 2007, citing Hoijer, 1933: 12–14)		
	Root	*Reduplicated form*	*Glosses*
a) /CVV-/	naa.toʔs	na.naa.toʔs *naa.naa.toʔs	*I step on it/REP*
	jaa.tsoʔs	he.ja.jaa.tsoʔs	*I see him/ several look at it*
b) /CVVC-/	soo**p**.koʔ	so.sop.koʔ *so**p**.sop.koʔ	*he swells up/I swell up (REP)*

In Samoan and Tonkawa, we can understand deletion as the solution to the coda problem – and Trevor chooses this solution, too, while many languages (like English) do not. More generally: every language has its own surface structures it will tolerate and those it won't. English is willing to disobey NoCoda more than Samoan will, but it won't put up with strings of vowels like [o.i.a] in (18a), nor will it permit Tonkawa's clusters like [mʔ] or [lʔ]. Thinking about very early child speech, it may have occurred to you that obeying all the possible structural constraints you have seen in every phonological problem set would result in a very, very simple set of surface forms – maybe just [ba.ba] and [baa]. And how exactly would such a grammar give you enough surface forms to build a lexicon?

So a constraint-based phonological grammar is built to do two things: first to filter out disprefered output structures, but second to maintain the material that's stored in underlying representations. This is accomplished via a second set of constraints, which each require that properties of the input be faithfully reproduced in the output. And one of these *faithfulness* constraints (as they are called) must be active in target English to preserve the final

[7] The transcriptions of [ts] and [mʔ] should not be understood as onset clusters but as affricates and glottalized singletons respectively.

segment of input '*cup*' by preventing its deletion. In the OT literature this constraint is called MAX, meaning that the input should be *max*imally preserved in the output, but we could also think of it as something more memorable – like Don't Delete.

(20) MAX (Don't Delete) first definition:
Assign a violation mark for every segment in the input that is not in the output

Now our tableau for any input with a potential coda needs to consider the demands of both NOCODA and MAX – because when considering an input like *cup*, they necessarily require different things! In Trevor's grammar, we know that NOCODA is obeyed – in contrast, MAX must be *violated*. In target English the reverse must be true, where MAX is obeyed at the expense of NOCODA:

(21a)

/kʌp/	NOCODA	MAX
[kʌp]	*!	
[kʌ]		*

(21b)

/kʌp/	MAX	NOCODA
☞ [kʌp]		*
[kʌ]	*!	

In OT terms, the difference between Trevor's grammar and that of his parents is not a question of which constraints they have, but *how they are ranked*. Note that this similarity between (21a) and (21b) is not just because they are both speaking (a version of) English, either. At least with respect to coda production, Trevor is speaking more Samoan than English, because their grammars share the ranking NOCODA >> MAX as in (21a), in comparison to target English in (21b).

The logical extreme of this argumentation is thus that all languages, whether child or adult, share the same set of constraints, both on output structures and on input faithfulness, and that the only difference between languages is the relative *rankings* of those constraints. This very strong hypothesis is a powerful one – it's almost certainly slightly wrong, but we will use the parallels between child and adult languages of the sort already seen to investigate how far it will take us. These continuities also represent key support for the idea that phonologies are driven by output-oriented constraints; they give us a way to describe the goals that children are aiming for when they produce non-target like words.[8]

[8] This way of connecting adult and child data is certainly not new; a famous version of it is found in Pinker (1984) under the name of the *Continuity Hypothesis* (Pinker, 1984: 7).

Before we move on, note to yourself that constraint ranking in OT is very all-or-nothing. Ranking Constraint 1 >> Constraint 2 does not suggest a tendency towards preferring candidates that obey C1 over C2, but rather imposes the harsh truth that *any* violation of C1 is worse than *every* violation of C2. In the present case, that means that any amount of deletion may be tolerated in order to satisfy higher ranking constraints, for example:

(22)

/kołd/	NoCoda	Max
[kołd]	*![9]	
[koł]	*!	*
[kod]	*!	*
☞ [ko]		**

At the broadest level, an OT grammar is a vast compromise between a number of mutually exclusive demands. Among pairs of constraints, though, it is a totalitarian regime.[10]

In another example below, Trevor's mapping of *stick* onto [tɪ] shows that his grammar ranks two structural constraints above Max, but doesn't tell us anything about their *relative* ranking. We indicate this indeterminacy in ranking with a dotted line: the notation in tableau (23) shows that NoCoda >> Max and *ComplexOnset >> Max, but doesn't claim anything else.

(23)

/stɪk/	NoCoda	*CompOnset	Max
[stɪk]	*!	*!	
☞ [tɪ]			**

Our next question: why should deletion be the only route to structural constraint obedience? The definitions of the structural constraint NoCoda in (16) provide no process or repair; NoCoda doesn't tell the learner *how* to avoid codas, it only tells the learner how dispreferred they are (to the tune of one violation per coda). The tableaus in (17) and (22) have already shown how the learner can consider many different potential

[9] Did you think this candidate should have two stars? Go read the definition of NoCoda again in (16).

[10] There are other constraint-based grammars which relax this ranking authoritarianism (called *strict domination*). The closest such OT relation is Harmonic Grammar, about which see Jesney and Tessier (2011) and references therein.

output candidates – but thus far they have all undergone varying degrees of *deletion* only. What else could we do to the input to satisfy NoCoda or *ComplexOnset?

One option has perhaps occurred to you from your previous phonology training, and it can be seen at work in some additional data from the beginning of the chapter's (1a) and (1d) children. Note that these output productions are from later in development, in the children's third year of life rather than their second:

(24a)

European Portuguese (data from Freitas, 2003)			
Target	*Child*		*Gloss*
/'gɾɐ̃dɨ/	['kɨ.ɾɐ̃:dɨ]	Luis (2;5.27)	*big*
/'pɛdɾɐ/	['pɛdɨɾɐ]	Luis (2;5.27)	*rock*
/'fɾaldɐ/	['fɨɾawdɐ]	Luis (2;5.26)	*diaper*
/'pɾẽdɐ/	[pɨ'ɾẽdɨ/	Laura (2;2.30)	*gift*
/'bɾɐ̃ku/	[bɨ'ɾɐ̃ːku/	Laura (2;2.30)	*white*
/'livɾu/	['livɨɾu]	Laura (2;8.23)	*book*
/bisi'klɛtaʃ/	[bisikɨ'lɛtaʃ]	Laura (2;11.4)	*bicycles*

(24b)

Trevor at 2;1 (Pater, 1996)						
growl	[gʌwauːz]	2;1.0		*spammeat*	[sʌpæːmiːt]	2;1.15
drip	[dɛwɪps]	2;1.14		*blow*	[bəwou]	2;1.17
plant	[pəwænt]	2;1.14		*squeak*	[gʌwik]	2;1.26
plate	[puwait]	2;1.14		*bright*	[bəwait]	2;1.5

In all of these words, *ComplexOnset is satisfied not by deleting a consonant but rather by *epenthesizing* a vowel.

Epenthesis as a cluster repair is not as common as deletion, both within and across child grammars. For Trevor, only 9/72 of his reported onset clusters at age 2;1 showed epenthesis, and likewise 55/2492 (2%) of the complex onsets in his corpus[11] were repaired with epenthesis. Similarly in Freitas (2003)'s longitudinal study of multiple Portuguese-learning children,

[11] As organized by Becker and Tessier (2011).

epenthesis accounted for only 9% of onset cluster attempts. Still, the pattern is clearly seen in many child grammars – and many adult grammars, too.[12] To see this we can return to the Yakuts data from (6). Previously, we saw a set of Yakuts words whose syllable shapes were all (C)V(C); but now we will look at the subset of those words which Yakuts has borrowed from Russian, and compare the Russian source and Yakuts borrowed forms:

(25)

Yakuts: More data (Schönig, 1988; Baertsch, 2002)		
Russian source	*Yakuts borrowing*	*Gloss*
[**pr**á.vi.lo]	[**bɪ.r**aa.bɪ.la]	*rule*
[**sr**e.dá]	[**se.r**e.de]	*Wednesday*
[**kn**í.ga]	[**kin**.gie]	*book*
[**sm**o.lá]	[**sɪ.m**a.la]	*resin, pitch*

With another potential /input/→[output] change comes the need for another faithfulness constraint: this time one with the effect of Don't Epenthesize. Its standard OT name in the literature is DEP, because it requires that every output segment must *dep*end (in a formal sense to be defined later) on an input segment, and thus that no output segment be novel.

(26) DEP (Don't Epenthesize) first definition:
Assign a violation mark (*) for every segment in the output that is not in the input.

As for its ranking: what is crucial about the ranking of DEP in Trevor's grammar (23) and the Yakuts' grammar (as in 25)? First, (27) establishes the definition of *COMPLEXONSET (that was your task above tableau (17)):

(27) *COMPLEXONSET (defined):
Assign a violation mark (*) for every syllable in the output that contains more than one onset segment.

To determine its crucial ranking compared with MAX and DEP, we can compare violations of some relevant output candidates in an *unranked table*

[12] In fact, target English provides some interesting evidence that epenthesis is a possible cluster-simplification strategy, albeit for dramatic effect. When someone over-articulates with disgust a word usually spelled 'puh-LEASE!', this output is understood as a variant of input /pliz/, which suggests that our common grammars understand vowel epenthesis into clusters to be a marginal but possible pattern.

in (28). Note that this is not a tableau, so it is not illustrating any particular grammar – it just assesses a set of potential input → output mappings, and how many violations each one incurs according to each constraint:

(28)

/spæm/	*COMPLEX ONSET	MAX	DEP
spæm	*		
pæm		*	
☞ sʌpæm			*

There are three constraints here, so there are six different rankings possible[13] – but as it turns out, there are only three different grammars. How can that be? Here are the two rankings that could *either* represent Trevor's grammar equally well:

(29a)

/spæm/	*COMPONSET	MAX	DEP
spæm	*!		
pæm		*!	
☞ sʌpæm			*

(29b)

/spæm/	MAX	*COMPONSET	DEP
spæm		*!	
pæm	*!		
☞ sʌpæm			*

Examining the two grammars in (29), you will find they share one crucial ranking: in both cases DEP is ranked beneath the other two constraints. It doesn't matter here what the ranking of MAX and *COMPLEXONSET is; so long as DEP is lowest-ranked, the optimal output is one that epenthesizes and does nothing else. We can consolidate this information with a standard ranking notation, where >> again indicates necessary rankings, and {} encloses constraints whose ranking with respect to each other is unimportant:

(30) *A fragment of Trevor's grammar at work in (24b)*
{MAX, *COMPLEXONSET} >> DEP

[13] Which is 3×2×1 or 3!, and so in the general case it will be n! for n constraints.

It can also be convenient (and sometimes more accurate) to simply list the crucial pair-wise rankings within a grammar – which are enough to choose the right winners, regardless of other rankings. In this case:

(31) MAX >> DEP
COMPLEXONSET >> DEP

Exercise 1: There are four more possible rankings of the constraints in (28), which create two other grammars. Draw a tableau like (29), and then determine the crucial rankings in those other grammars as in (30). Does each one correspond to a child and/or adult language we have already seen?

Exercise 2: This exercise is a topic for your own thought. Given what you have learnt so far in this chapter, consider the extent to which children learn to talk by imitating.

3.4 More Choices in Optimization

3.4.1 A Role for Sonority

We will next tackle more questions of how the grammar and the child deploy their repair strategies, by asking about the range of output candidates they can assess. In the child data where clusters undergo deletion, we have simply noted the disappearance of a consonant as being a method to obey a structural constraint. But how did the grammar choose *which* segment to delete? Why is *stick* pronounced [tɪk] and not *[sɪk]? In most cases, children's productions reveal systematic targets for deletion, and so we must find a way to capture them. We will focus mostly on onset clusters, in part because they are so well studied.

In Chapter 1's discussion of cross-linguistic phonotactics, we saw that grammars often impose restrictions on clusters in terms of their segments' relative *sonority*. Sonority also turns out to be a major determinant of how cross-linguistic learners repair the target clusters which their current grammar rules out. We begin in (32) below with one group of clusters with a similar sonority profile, in English, Hebrew and Dutch. Examine these three data sets, and describe the patterns in terms of sonority: what kinds of clusters are found in these target inputs, and which member of each such cluster is deleted in the output:

(32a)

G (Gnanadesikan, 1995/2004)				
clean	[kin]		*please*	[piz]
sleep	[sip]		*friend*	[fɛn]
slip	[sɪp]		*draw*	[da]
grow	[go]		*cream*	[kim]

(32b)

SR learning Hebrew (Bloch, 2011: 32–33)			
Target	*Child*	*Gloss*	*Age*
/ˈglida/	[ˈgidɑ]	*ice cream*	1;06.12
/ˈtʁaktor/	[ˈtaktor]	*tractor*	1;06.12
/klaˈvim/	[kaˈvim]	*dogs*	1;09.09
/bʁeˈxa/	[beˈxaa]	*swimming pool*	1;11.02
/blonˈdini/	[boˈdini]	*blonde*	2;02.02

(32c)

Dutch (Data from Fikkert, 1994)			
Target	*Child*	*Gloss*	*Age*
/kla:r/	[kɑ]	*ready*	J 1;4.18
/klɔk/	[kɒk]	*clock*	J 1;6.27
/trɛintjə/	[tɑɪtɑ]	*train*	1;7.15
/bru:k/	[bu:k]	*trousers*	1;9.21
/plɑsən/	[pa:sə]	*to pee*	1;10.15

If we create a list of all the target clusters in (32), we will fairly soon find a clear pattern in their featural make-up. All these clusters consist of stops or fricatives, followed by liquids and glides – put more generally, obstruents followed by sonorants.[14] With these two categories in mind, we see all of these clusters are simplified by deleting the sonorant and preserving the obstruent.

Now: what kind of structural constraint should be built to capture this pattern? (We will see its presence in adult phonologies too, in a few pages.) If all we need to do is prefer obstruents over sonorants in onset – why not a constraint that imposes this binary distinction?

(33) *SONORANTONSET – *tentative*
Assign a violation mark for every syllable with a sonorant segment in its onset

For all the inputs in (32), this constraint will do the right work, as shown in (34). But can you come up with possible inputs where this won't be enough?

[14] It is true that sonorants include nasals, but in fact nasals often pattern somewhat differently than liquids and glides in this cluster environment. We will not say much about nasals in onset clusters in this chapter, although they will make a brief appearance below.

(34)

/slip/	*ComplexOnset	*SonorantOnset	Max
slip	*!		
lip		*!	*
☞ sip			*

Here's the insufficiency of (34): while obstruent+sonorant clusters are no doubt the most common onset clusters across languages, many onsets include more than one member of either class – and (33) will have nothing to say about how they are repaired. Below in (35) are examples of two such cluster types in child speech: French onsets that contain two sonorants, and Polish onsets that contain two obstruents. In the latter case, notice that the clusters include fricatives, stops and affricates in multiple orders. …Thinking beyond (33), can you see how sonority plays a role in simplifying the clusters below?

(35a)

French (Rose, 2000: 96, 99)			
Target	*Child*	*Gloss*	*Age*
/lwa'zo/	[lɑ'zɔ^{ʊ}]	*the bird*	C, 1;4.07
/ljɔ̃/	[lɑ]	*lion*	C, 1;4.07
/mjam/	[ma]	*yum*	T, 2;0.21
/pwasɔ̃/	[pɔsɔ]	*fish*	T 2;4.28

(35b)

Polish (Lukaszewicz, 2007: 58)		
Target[15]	*Child*	*Gloss*
/fpatw/	[pat]	*he burst into*
/d͡ʒvi/	[dzi]	*doors* (nom.)
/spɔtkaw/	[pɔtkaw]	*he met*
/xt͡ɕawam/	[tsawam]	*I wanted*
/kɕɔ̃w̃ʃka/	[kɔ̃w̃ska]	*book* (nom.)
/stɔnt/	[tɔnt]	*from here*

What these clusters emphasize is that survival or deletion of segment within a cluster depends not on its *absolute* sonority – but on its *relative* sonority, compared to the other segments around it. Is [l] a bad onset segment? If the alternative is something *less* sonorous, then yes: so [l] deletes in *play*, or *flower* or

[15] The segments with tie bars in these inputs are affricates.

sleep (as in 32). But if the alternative to [l] is *more* sonorous, like a [w], then no: [l] won't delete (as in 35a). The upshot is that when reducing an onset cluster, these grammars delete the most sonorous segment *available in the input*.

How do we impose these relative restrictions? All we need is a more articulated onset constraints – one for each step on the sonority hierarchy, so that *SONORANTONSET is replaced by a family like *FRICATIVEONSET, *LIQUIDONSET, *GLIDEONSET and so on. With this constraint family, our existing OT architecture provides the mechanism for relative choices: rankings!

(36a) The Onset Sonority hierarchy (replacing *Sonorant Onset)
(see related constraint definitions in Prince and Smolensky, 1993/2004 and Pater and Barlow, 2003)

*GLIDEONSET	Assign a violation mark for every onset containing a [+vocalic, −syllabic] segment
*LIQUIDONSET	Assign a violation mark for every onset containing a [+approximant, −vocalic] segment
*NASALONSET	Assign a violation mark for every onset containing a [+sonorant, −approximant] segment
*FRICONSET	Assign a violation mark for every onset containing a [−sonorant, +continuant] segment

(36b) *GLIDEONS >> *LIQUIDONS >> *NASALONS >> *FRICONSET

The order in (36b) is a *fixed ranking*. In other words, we will treat it as a given in <u>every</u> grammar that these constraints are ranked as in (36b), whereby the higher the sonority of a segment, the higher-ranked its *ONSET constraint. The three tableaus in (37) now show how this fixed ranking ensures the effects of *relative* sonority in onset cluster reduction:

(37)

		*COMPLEX ONSET	*GLIDE ONSET	*LIQUID ONSET	*NASAL ONSET	*FRIC ONSET	MAX
a)	/slip/						
	slip	*!					
	lip			*!			*
	☞ sip					*	*
b)	/mjam/						
	ja		*!				*
	☞ ma				*		*

Continued

		*COMPLEX ONSET	*GLIDE ONSET	*LIQUID ONSET	*NASAL ONSET	*FRIC ONSET	MAX
c)	/stɔnt/						
	sɔnt					*!	*
	☞ tɔnt						*

Note: the shading of columns above is a standard way to indicate constraints which are irrelevant to the ranking decisions of a particular tableau. In (37a), the two losing candidates are ruled out by *COMPLEXONSET and *LIQONSET, so all the constraints ranked lower are shaded out; in (37c) however, the lower-ranked *FRICONSET is crucial to choosing between the two potential candidates, so only MAX is shaded out. Shading will be used sporadically through the text, to highlight the importance of constraints in more complicated tableaus, but you are encouraged to use it wherever it helps to clarify your analyses.

Exercise 3: Which of the rankings in (37) are we sure of? For example, to make sure all the right candidates win, does MAX really need to be ranked at the very bottom of this tableau? Given the candidates under consideration here: could you move it higher in the ranking and get the same result? What about the crucial rankings of *COMPLEXONSET?

Notice that in the Polish example (37c), our fixed ranking chooses the least sonorous onset segment (a stop rather than a fricative) even in the exceptional case of reversed sonority, that is where the first segment is *more* sonorous than the second. The data in (35b) demonstrated that Polish allows a myriad of such clusters – but recall that English, Hebrew and other languages also tolerate one such reversed cluster, namely [s]+stop.[16] Returning to the children from (32), the data excerpts below show that those children's grammars also reduce fricative+stop clusters to their least sonorous member (the stop) – at least most of the time. For G, no exceptions to this pattern were reported, while in the two Hebrew-learning children's corpora the pattern holds 85% of the time.

(38a)

	G (Gnanadesikan, 2004)				
	sky	[gaj]		*skin*	[gɪn]
	spill	[bɪw]		*spoon*	[bun]
	straw	[dɑ]		*star*	[dʌ:]
c.f.:	*snow*	[so]		*sleep*	[sip]
	snookie	[sʊki]		slip	[sɪp]

[16] Hebrew in fact allows many more, as you will soon find out.

(38b)

SR and RM learning Hebrew (Bloch, 2011: 39–40)			
Target	*Child*	*Gloss*	*Age*
/ʃtaim/	[taim]	*two (fem.)*	RM (1;09.27)
/ʃtaim/	[θaim]	*two (fem.)*	SR (2;00.05)
/ski/	[ki]	*ski*	SR (1;07.17)
/sgu'lim/	[gu'lim]	*purple (masc. pl.)*	RM (2;02.11)
/stam/	[sam], [taj]	*purposelessly*	RM (2;04.19
/spa'geti/	[pa'geti]	*spaghetti*	SR (1;09.12)

Taking a cross-linguistic step back, we can see the influence of this Onset Sonority hierarchy in a variety of target language patterns. A fairly comparable one is seen in Pali, an Indo-Aryan language once spoken in India and elsewhere, and used as the literary language of Buddhist scriptures. Pali's syllable structure restrictions mean that stringing together morphemes in the input often creates illegal surface clusters which must be repaired. Examine the data in (39), and consider which member of those clusters survives:[17]

(39)

Pali (data here from de Lacy, 2002: 483–486, citing Fahs, 1985)					
Input	*Output*	*Gloss*	*Input*	*Output*	*Gloss*
/d^{h}ov-ta/	[d^{h}o.ta][18]	*to clean*	/kar-ja-ti/	[kir:ati]	*make*
/lag-na/	[lag:a]	*join*	/sak-ʃ:a-ti/	[sak:^{h}ati]	*be able to*
/gam-c:a/	[ga:ca]	*go*	/lip-ja-ti	[lip:ati]	*scrawl*
/das-ja-ti/	[dis:ati]	*see*	/k^{h}an-ja-ti/	[k^{h}aɲ:ati]	*dig*

Just as in the child grammars we have been analysing, the Palian grammar handles input consonant clusters by deleting the more sonorous member and keeping the less sonorous one. To see the need for relative sonority, compare the forms meaning 'go' and 'dig' below:

[17] A few other processes are going on here as well: first, sometimes the surviving consonant is *lengthened*; second, /n+j/ comes out as a palatal nasal. Both patterns will be echoed in child data to come.

[18] [dhovita] is also cited as an alternative output.

(40)	a)	/ga<u>m-c</u>:a/	→ [ga:ca]	/nasal + stop/ → [stop]
	b)	/kʰa<u>n-j</u>a-ti/	→ [kʰaɲ:ati]	/nasal + glide/ → [nasal]

Upshot: relative sonority, encoded via an *Onset hierarchy, will account for a lot of child cluster reduction. So far so good! As it turns out, the Hebrew cluster reduction facts are more complicated than a sonority-only account can handle – but let's put this problem on hold for a section, and get a bit of perspective on what we've done so far.

3.4.2 Thinking Through the Candidate Set

An important piece of any OT analysis is to examine all of the grammatical rankings accumulated for a particular language, to make sure none are contradictory (a sure sign of trouble!) and then to assess whether further output candidates must be considered. This last point is one we will now attempt to address: what IS the range of output candidates that the grammar provides, or that the learner entertains?

In a rule-based grammar, there is no need to imagine the output of a derivation before one applies a rule – if the context of a rule is satisfied, its change occurs, and whatever comes out, comes out. But evaluating an input in OT means considering a range of fully-formed output candidates, in light of each ranked constraint, and so we must define that range. Where do the outputs come from?

The strong(est) OT hypothesis is that *every potential output* is under consideration when mapping any input to its optimal output. Just as every language has the same constraints, but in a different ranking, so <u>every mapping in every language has the same set of potential output candidates</u> – although each mapping is made with reference to a particular input and a language-specific ranking. This may sound terrifying for the learner or analyst or both[19] – but for this text's purposes, we will always try to build a set of limited relevant candidates, with some support from a proven property of OT called *harmonic ascent* (Moreton, 2004).

Speaking somewhat informally, this property tells us that given a particular set of structural and faithfulness constraints in an OT grammar, every input can only be mapped in one of two ways. Either (1) it can be fully

[19] Particularly because this output set is, given only what we've seen so far, infinite! If one way a candidate can differ from its input is through epenthesis of a segment, and in many cases multiple segments – then how could there be a principled bound on the number of epentheses possible? If there is none, then the candidate set can grow infinite larger with more and more epenthesis. If this really bothers you, you might want to read Riggle (2004).

faithful (meaning that it doesn't violate any faithfulness constraints, and so no segments are deleted or inserted or otherwise structurally changed) or else (2) it can be mapped to some unfaithful candidate, but only if that unfaithful candidate fares better on one or more structural constraints than it would by simply being faithful. The upshot of harmonic ascent is that when you have an input and a set of constraints, and you are trying to find an output winner, you must always consider the fully faithful output candidate, and then look at those candidates that better satisfy some structural constraint(s), but are otherwise as faithful as possible. From that set, you will find your winner.

To put this into practice, let us consider the constraints we have and their necessary rankings for children like G and others who repair onset clusters by deleting their most sonorant member. We have seen two key groups of rankings for this grammar: the first below ensures that complex onsets are repaired via deletion, and the second encodes the notion that the lower sonority an onset, the better:

(41) {*COMPLEXONSET, DEP} >> MAX
*GLIDEONS >> *LIQUIDONSET >> *NASALONSET >> *FRICATIVEONS

We know that when faced for example with the input '*play*', a grammar with the rankings in (41) will map /pl/ → [p]. That winning output candidate [pej] is as good as we need to get, harmonic-ascent-wise, because it violates *none* of the structural constraints we have, and violates the *lowest ranked* faithfulness constraint, MAX.

But what if that liquid onset had been the only one? Suppose the input was '*lay*'? What does this grammar predict? It turns out that we need more rankings between our constraints to decide. For instance, if MAX is ranked at the very bottom of the grammar, look what happens!

(42)

/lej/	*COMPLEXONSET	DEP	*LIQUIDONSET	MAX
lej			*!	
☞ ej				*

Now '*lay*' also loses its liquid onset! Perhaps it wasn't obvious when these constraints were introduced, because we were only comparing candidates like [pej] vs. [lej] – but now you can see that the onset sonority constraint hierarchy from (36) will in fact insist, if given its way, that every onset be a stop, since stops are the least sonorous manner of consonant and the only one not penalized by any of (36)'s constraints.

Is this prediction at all right? Mostly, no. It is indeed true that some sonorant consonants like [l] and [ɹ] are often acquired quite late, and sometimes they are even deleted (much discussion to follow in Chapter 5). But certainly this is not the general rule. Furthermore, it is certain that the children in (32) produced sonorants as singleton onsets – in fact, G's mother reports that at this stage, all of G's /ɹ/s and /w/s were produced as [w], so clearly onset glides were permitted. So how could these /ɹ/s and /l/s be treated different in for example *lay* versus *play*?

You can probably come up with an intuitive explanation, which goes something like this: In *play*, there is a structural problem to be solved, namely the illegality of onset clusters, but in *lay*, there is no such <u>independent</u> demand for deletion. And this intuition can be captured using our existing constraints, merely by adjusting the ranking. Do you see how? Before you continue, draw a tableau for yourself, replicating (42) but with the opposite result (mapping /lej/ → [lej] faithfully, rather than pushing it to *[ej]) – and then read on.

***

Here is a ranking that does the trick:

(43) {*ComplexOnset, Dep} >> Max >> *Glide/Ons >> *Liquid/Ons (and so on).

Sandwiching Max with *ComplexOnset above it and the Onset Sonority hierarchy beneath it will capture both the cluster reduction and singleton preservation facts. When there is just a singleton, the maths is simple: faithfulness is more important than the sonority of any singleton onset:

(44)

/lej/	*Complex Onset	Dep	Max	*Glide Onset	*Liq Onset	*Nasal Onset	*Fric Onset
☞ lej					*		
ej			*!				

In a cluster, on the other hand, the highest-ranked structural constraint means that repair is unavoidable (ruling out 45a below). The ranking Dep >> Max means that repair will be deletion (ruling out 45b), so that the lower-ranked Onset Sonority constraints have a say, in which segment to delete:

(45)

	/plej/	*COMPLEX ONSET	DEP	MAX	*GLIDE ONSET	*LIQ ONSET	*NASAL ONSET	*FRIC ONSET
a)	plej	*!				*		
b)	pəlej		*!			*		
c)	lej			*		*!		
d)	☞ pej			*				
e)	ej			**!				

Both candidates (45c) and (45d) violate MAX equally – and so the decision is passed down to the lower-ranked sonority constraints, where *LIQUID/ONSET does the work of deleting the input's higher sonority segment, choosing (d) over (c).[20] Finally, notice that (45e) is ruled out by MAX – because while it fully satisfies the top two constraints and the Onset Sonority hierarchy, it fails due to its excessive deletion. No constraint above MAX is better satisfied by deleting both onset segments rather than just one, so candidate (e) loses out to (d) as well.

3.4.3 Other Cluster Reduction Grammars

While sonority-driven reduction is perhaps the most common child treatment of onset clusters, it is by no means the only one. Other structural pressures can compete with sonority considerations to determine which segment gets deleted – and here is one such example, taken from other Hebrew onset cluster types produced by two children, RM and SR. (Note: at this stage, both of these children produce /s/ → [θ] across the board, not just in this phonological environment.)

(46)

	More Hebrew cluster acquisition (Bloch, 2011: 36, 45)					
	RM			SR		
	Target	*Child*	*Gloss*	*Target*	*Child*	*Gloss*
a)	/tmu'not/	[tu'not]	*pictures*	/ʃne'hem/	[θe'em]	*the two of them*
	/ʃnej/	[se]	*two*	/sna'it/	[θa'ʔit]	*squirrel (fem.)*
	/kmo/	[ko]	*like*	/tni/	[ti]	*you give (fem.)*

Continued

[20] This isn't the only approach to making sure singletons survive, mind you. A different problem with deleting the [l] in *lay* is that the output has no onset! Try out that grammar, using the constraint from (12), and think about which rankings you need.

	RM			SR		
	Target	*Child*	*Gloss*	*Target*	*Child*	*Gloss*
b)	/ʃnej/	[ne]	*two*	/'ʃmone/	['mone]	*eight*
	/kmo/	[mo]	*like*	/kmi'tsa/	[mi'θa]	*ring finger*
	/smi'xa/	[mi'xa]	*blanket*	/tmu'na/	[tmu'na]	*picture*

These inputs all begin with an obstruent followed by nasal – and the output is decidedly mixed, with both children sometimes deleting the nasal (the more sonorous segment), but often deleting the obstruent instead. Note that the discrepancies in these data do not come from two different stages of development – this variability was seen at 2;02 all the way to 2;10, in one word or another.

How should we analyse these two patterns in (46)? As a first approximation, suppose that there are two grammars at play in this data: one that explains (46a) and another that chooses (46b). (This approach means we will also have to figure out how two grammars exist at once in one child, but one problem at a time.) With respect to (46b) then: [s]+nasal clusters in English are also sometimes reduced to their nasal rather their fricative, so perhaps there is something generally weird about /C+nasal/ inputs.[21] But from the OT perspective, this weirdness must be understood as the result of competing pressures. That is, *NasalOnset prefers the outputs in (46a), but what prefers (46b)?

One final set of data from Hebrew may help us see a pattern. Like Polish, Hebrew allows a variety of obstruent+obstruent clusters, not just [s]- and [ʃ]+stop – and in SR's grammar, there is a consistent explanation for which segment gets deleted, but it is <u>not</u> sonority-driven:[22]

(47)

SR's obstruent+obstruent Hebrew onsets (Bloch, 2011: 53)					
Target	*Child*	*Gloss*	*Target*	*Child*	*Gloss*
/kfits/	[fiθ]	*spring*	/ktanim/	[ta'nim]	*small (masc. pl.)*
/dvo'ʁa/	[va'ʁa], [da'ʁa]	*bee*	/ktanot/	[ta'not]	*small (fem. pl.)*

Continued

[21] For related arguments see for example Pater and Barlow (2003) on English; Yavaş et al. (2008) especially about Hebrew; Kristoffersen and Simonsen (2006) on Norweigan.

[22] In this way, the Hebrew facts are different from those found for Polish in (35a). Remember, however, that we are looking in depth at a few children, rather than across a large data set, so we cannot say much about language-specific vs. child-specific tendencies. For what it's worth, the dominant pattern here in SR's data also holds, to a lesser extent, in RM's Hebrew data as well.

Target	*Child*	*Gloss*	*Target*	*Child*	*Gloss*
/ˈtxelet/	[ˈxelet]	*light blue*	/gdola/	[doˈla]	*big*
/gviˈna/	[viˈna]	*cheese*	/gdolot/	[doˈlot]	*big (fem. pl.)*
/kviˈsa/	[viˈsa], [kiˈsa]	*laundry*	/pkak/	[kak], [pak]	*cork*
/tsvi/	[vi]	*gazelle*	/ktana/	[taˈnaa], [kaˈna]	*small (fem.)*
/zvuv/	[vuv]	*fly*			
/tsvaˈim/	[vaˈʔim]	*colours*			
/tsvaʁˈde.a/	[faˈde.a]	*frogs*			

In all of (47), it is not the sonority of a segment that determines its fate in a cluster, but its position – the second member of cluster, the one closest to the vowel, is the one which predominantly survives. Can you imagine a constraint that would capture this pattern?

The additional tool that we will use to capture this ordering fact is a faithfulness constraint, proposed in the OT literature to explain other target language patterns, which prefers output strings to be *contiguous* in the input. This constraint (simply called CONTIGUITY[23]) always prefers /C_1C_2V/ → [C_2V] in every case, simply because the alternative *[C_1V] involves two segments which are contiguous in the output but not the input.

The contiguity-driven account of SR's onset cluster grammar can be explained informally as follows. When sonority differences between onset cluster members are sufficiently big (i.e. obstruent+approximant), the Onset Sonority constraints conspire to delete the more sonorous one (as in 32b). But when all onset options are fairly low sonority (i.e. all obstruents), then sonority is deemed irrelevant and CONTIGUITY is allowed to choose the second member (47).[24] The case of obstruent+nasal (46) represents a middle ground: sometimes the sonority gap between obstruent and nasal seems big enough to matter, and sometimes it doesn't. (This sketch does not provide the details of this account, but it at least demonstrates the kinds of competing pressures that may drive complicated patterns of syllabification – and faithfulness to input contiguity is a phonological pressure you may see again on your travels.)

[23] See McCarthy and Prince (1995).

[24] In this grammar, then, the fact that /s/+stop → [stop] happens to choose the least sonorous output segment, but that is just a happy accident. It is really only because the input /stop/ was contiguous with the vowel that it survives.

3.4.4 More Competition: Word-Medial Clusters

Our last foray into child cluster reduction turns to Spanish, and the relative acquisition of consonant clusters under different syllabifications. The data below introduce two different children's treatment of Spanish consonant clusters in the middle of words – this means that these clusters could either be syllabified as complex onsets (V.CCV) or coda-onset strings (VC.CV).

First we will examine the word-internal clusters of one child, anonymized as BL4[25], recorded at age 2;8. To understand the pattern, you will need to look at word-initial clusters (i.e. onsets), and then the range of word-medial CCs. Before reading on, describe BL4's syllable structure restrictions in your own words. (Recall that [tʃ] is an affricate, a single segment, and so does not violate *ComplexOnset!)

(48)

	BL4's Spanish at age 2;8 (Barlow, 2005)						
	Target	*Child*	*Gloss*		*Target*	*Child*	*Gloss*
a)	/plato/	[pato]	*plate*	c)	/manzana/	[manzana]	*apple*
	/bloke/	[boke]	*block*		/dulses/	[dulses]	*sweets*
	/fresa/	[fesa]	*straw berry*		/falda/	[falta]	*skirt*
	/tren/	[ten]	*train*		/arbol/	[albol]	*tree*
b)	/tʃikle/	[tʃike]	*gum*		/kumpleaɲos/	[kumpeaɲos]	*birthday*
	/negro/	[nego]	*black*		/sombrero/	[sombelo]	*hat*

At the beginning of words (48a), BL only allows one onset segment, so clearly no complex onsets are permitted. This provides a good understanding of why some clusters are reduced in the middle of words (in 48b) and yet others survive (48c). If you were to syllabify the targets in English, you would already see a difference: words like *chi.cle* would have a complex onset, but those like *fal.ta* would have a coda followed by an onset (compare them to English words like *an.klet* and *fal.ter*). If BL4 is using the same syllabification strategies as English does, then we can understand their grammar as one in which no complex onsets are allowed, but codas are permitted:

(49) BL4's cluster grammar:
*ComplexOnset >> Max >> NoCoda

[25] This child was a Spanish-English bilingual (both were learning Mexican Spanish in southern California), but there is no indication that knowledge of English is necessary to get this pattern.

(As for why 48b words can't hang onto their cluster by syllabify it as *neg.ro* – good question! But wait till Chapter 6.1)

Now, however, compare BL4's productions with those from another child in the same population:

(50)

	SD1's Spanish at age 3;4 (Barlow, 2005)						
	Target	*Child*	*Gloss*		*Target*	*Child*	*Gloss*
a)	/plato/	[plato]	*plate*	c)	/kampanas/	[kapanas]	*bells*
	/bloke/	[bloke]	*block*		/fuente/	[fuete]	*water fountain*
	/fresa/	[fɾeda]	*straw berry*		/gantʃo/	[gatʃo]	*hook*
	/tren/	[tɾen]	*train*		/delfin/	[ofi]	*dolphin*
					/dulses/	[duθes]	*sweets*
b)	/tʃikles/	tʃikles	*gum*		/estreja/	[etɾeja]	*star*
					/tʃaɲklas/	[tʃaklas]	*sandals*

In word-initial vs. word-medial clusters, this child SD1 appears to be the mirror opposite of BL4!: complex onsets are permitted (50a) and so retained word-medially (50b), while word-medial codas are reduced (c).

However: what is the structural constraint that bans surface forms in (c), like *[gan.tʃo]? The interesting analytic point is that this candidate cannot just be NoCoda (i.e. it is not a mirror image of 49) because words like [tɾen] and [tʃaklas] demonstrate that nasal and fricative codas are, in fact, grammatical. What is not allowed is a coda-onset *sequence*, or a word-internal coda, and for that precise ban we have as yet no constraint.

The cross-linguistic typology of adult language makes clear that word-internal and word-final codas often pattern differently in the same grammar, which requires that they be targeted by different structural constraints (more on that in a moment). In this case, it appears that there is something especially dispreferred about a word-internal coda (see similar observations in e.g. Fikkert (1994) on Dutch, Freitas (1997) on European Portuguese, and Rose (2000) on Quebec French.) Thus, suppose that we add a structural constraint which prohibits just those codas that precede an onset:

(51) *SyllableContact (first pass)[26]
Assign a violation mark for every coda which is followed by a onset.

[26] On this type of constraint, see especially Gouskova (2004) and many pre-OT references therein.

(Notice that this isn't quite the same as banning all word-medial codas – while they are exceptional, there are times when a language might syllabify a string as /VC.V/, which would not violate *SyllableContact.)

This constraint can be the one that rules out (50c)'s input clusters in SD1's grammar, while NoCoda can remain low-ranked to allow final codas. To make sure you see how this works, draw in the violations for these two mappings in SD1's grammar, and indicate the winner beside its letter (answers at the end of the chapter):

(52)

	/tʃaɲklas/	*Syllable Contact	Max	*Complex Onset	NoCoda
a)	tʃaɲ.klas				
b)	tʃaɲ.kas				
c)	tʃa.klas				
d)	tʃa.kla				

<u>Exercise 4:</u> Where must *SyllableContact be added to the ranking in (49) to ensure that BL4's grammar still captures the data in (48)?

We now have two constraints against codas in our constraint universe: NoCoda, which penalizes them in all contexts, and *SyllableContact, which bans a subset of them. Taking a step back, this means we can now predict three kinds of languages: ones in which languages tolerate codas in *no* contexts, in *all* contexts, or just word-finally. These three patterns certainly exist in target languages – Chapter 1 mentioned Hawaiian as a coda-less language; English is an example of the coda-ful pattern, and Luo (a Nilotic language spoken in Kenya and Tanzania) provides the intermediate case, where only word-final codas are allowed.

But the language we can*not* capture is one in which word-internal codas are <u>allowed</u>, but word-final codas are <u>banned</u>. Do you see why? There is no way to derive the following two mappings simultaneously:

(53) *Impossible grammar given constraints in (*52):
 a) medial codas saved: /VCCV/ → [**VC**.CV], and not *[V.CV] *but also*
 b) final codas banned: /VC/ → [**V**], and not *[VC]

To generate (53a), both constraints against codas must rank below Max. But if so, nothing can cause unfaithfulness in (53b). (If you can't see it yet, draw the tableaus for yourself!) This is the predictive power of a universal set of constraints: and in this case, it reveals how powerfully wrong we are, because languages like (53) are not hard to find – for example, the not-so-exotic language of Italian.

The upshot, then, is that a full account of coda distributions across languages will need more structural constraints than just NoCoda and *SyllableContact. One analytic idea is that in some (or even all!) languages word-final consonants are not actually codas, but rather sit somewhere else in the prosodic hierarchy; maybe they are onsets in disguise (Kaye, 1990; Piggott, 1999; Harris and Gussman, 2002), or maybe they are not part of any syllable at all. Adding this option into the analytic mix allows for adult languages like Italian, but it then also allows for different interpretations of the child grammars seen above for BL4 and SD1 (for more on this topic, see arguments in Goad and Brannen, 2003, also taken up in Barlow, 2005).

3.5 Consequences and Alternatives

This chapter's extended discussion of consonant cluster reduction and sonority-driven accounts has aimed to give you a first in-depth example of OT analysis. In doing so, we have faced some of the crucial questions that must be asked and that also can be answered using the theory's architecture and assumptions.

Let's now take stock! This section deals with three types of discussion points: more about the data, more about the theory, and a first pass at framework-comparison.

3.5.1 More about the Data

One big empirical question we will always return to is the question of individual variability, and the extent to which the syllable structure patterns discussed thus far are universal and exceptionless – which, at the broadest level, you already know they are not. In Section 3.3.3, we already suspended the notion that each stage of development is captured by a single invariant ranking, in trying to understand how Hebrew-acquiring children treat obstruent+nasal clusters.

One kind of between-child variation suggests that the earliest stages of phonological *production* may not coincide with the initial state of phonological *learning*. For instance, the very first stages of speech overwhelmingly prefer CV structures, yet it is certainly the case that some children's earliest words also include VC and CVC syllables – see for example Vihman (1981) on Estonian, Grijzenhout and Joppen (1998) for German, and Khattab and Al-Tamimi (2011) for Lebanese Arabic.

However, there also seem to be some clear language-specific differences in earliest syllable structure preferences, and in particular some which counter the universal syllable pressures encoded in our syllable structure constraint set above. As a striking example, Savinainen-Makkonen (2000a) reports on a process of word-initial consonant omission in very young children especially learning Finnish, typically before age 2; some of the details will be discussed in Chapter 5.2.3. Interestingly, the several children learning European Portuguese (whose cluster reduction and epenthesis we have already seen) also occasionally handled initial clusters by deleting the entire thing:

(54)

European Portuguese (Data from Freitas, 2003)			
Target	*Child*	*Gloss*	*Age*
/ˈgɾɐ̃dɨ/	[ˈɐ̃ŋi]	*big*	J (2;2.28)
/bisiˈklɛtɐ/	[pisiˈɛtɐ]	*bicycle*	L (2;0.27)
	[ˈɛtɐ]		J (2;4.30)
/ˈbɾuʃɐ/	[ˈũgɐ	*witch*	J (2;2.28)
/ˈpedɾu/	[ˈpe.u]	*Peter*	J (2;4.30)
/floɾ/	[ˈolɨ]	*flower*	I (1;9.19

These cases of entire cluster deletion are rare, and unattested in many child- development studies, but they are also as yet unexplained in our theory-building. It might be suggested that these clusters are particularly difficult for children to reproduce because they are *unstressed* – but at the very least, it will do nothing to explain Finnish word-initial deletions, since those all occur in stressed syllables. (For more explanation of that last sentence, wait till Chapter 4.)

A further cause of variability might always come from perception vs. production skills. What if children misperceive more complicated syllable structures as simpler ones? Can that account for cluster reduction and simplification? Looking at the data you have seen thus far, there are a couple reasons to be suspicious about a wholesale appeal to perceptual explanations. For instance: it seems unlikely that BL4 systematically heard *no* onset clusters but *all* medial clusters, while SD1 did precisely the reverse. It may also strike you that misperceiving a cluster by failing to hear a segment is more plausible than misperceiving the existence of a vowel – that is that cluster 'deletion' could be better explained by misperception than cluster 'epenthesis'.[27]

[27] This may well be right, although you should know that lots of adult second language learner misperceive clusters as containing illusory vowels – see Dupoux et al. (1999).

However, we will delay this discussion of perception until we have a few more pieces of the empirical puzzle in place.

3.5.2. More about the Theory

This chapter has introduced the workings of Optimality Theory, starting from scratch but moving quickly. There are therefore many areas of the theory currently left very sketchy; the next chapters will do some of the larger fleshing out, but let us at least tackle a couple of big issues.

3.5.2.1 More about Representations

The first issue is all about syllables and representations, and all the questions of where and how syllables are represented in the grammar. The descriptions of child data here have been mostly agnostic about any subtleties of syllable structure, especially concerning nuclei – more must be said in a fuller description of child phonology regarding vowel length and diphthongs, and moraicity, as well as the syllabic constituent called the *rime*, '*extrasyllabic*' segments and so on. For at least a start on syllable structure and its roles in child phonology, see the further readings listed at the end of the chapter.

Another crucial question, necessary to fully implement any OT evaluation, is to determine which strings in the grammar actually contain syllable structure. At the beginning of the chapter, we assumed that inputs come unsyllabified to the learner's grammar: inputs look like /CVCVC/ and outputs look like [CV.CVC]. It is instructive to note that this is also the usual assumption about adult grammars, but for different reasons. The already-mentioned reason for leaving syllable structure out of adult inputs is that syllabification is never *contrastive*: once you know the language-specific grammar, syllabification should always be predictable, and therefore needn't be stored in the lexicon. Regardless of whether this reasoning is sound, the fact that syllabification is never contrastive can be captured simply in OT <u>by excluding any constraints that are faithful to syllabification.</u> If there is no such faithfulness constraint – that is no constraint like 'MAX-ONSETSEGMENTS' – then no amount of syllable structure in the input will have any effect on the choice of optimal output.

Easy enough, as far as it goes – but this question extends to many other questions about whether child and adult inputs are the same type of representation. If we think that children's inputs are taken from the target forms, heard as adult <u>outputs</u>, this puts them in sharp contrast with the usual notion of underlying representations attributed in a phonology textbook to an adult native speaker – in the latter case, we usually posit the input as some abstract mental representation, not a fully-formed output. Such abstract inputs used by adult grammars might have underspecified segments, or archiphonemes or floating features, or no stress, or all of the above – but if a child's <u>input</u> is built from an adult's <u>output</u>, it will never contain any of these unpronounceable things, and will also contain some potentially redundant things too. So perhaps the inputs to a child's phonology are special with respect to syllable structure too? Perhaps! In fact, Chapter 4 will present a pattern whose most promising account <u>requires</u> that syllables be assigned in some way to input representations. But again, it is worth noting that in OT terms, adult inputs can, in fact, contain as much redundant detail as you like, so long as what's crucial to the phonology is captured and regulated by constraints.

3.5.2.2 More about Constraints

A third topic which we will simply flag for now concerns the definitions and the sources of the grammar's structural pressures: what are the limitations on the definitions of constraints? And where do constraints come from?

These are both very big questions, and they loom analogously large for any phonological enterprise, working in or out of acquisition, in any framework. For example: any theory of phonology, governed by rules or constraints or otherwise, is frequently faced with decisions as to which *boundaries* or *junctures* can be referenced in a rule – whether syllable, morpheme, compound stem, word, intonational phrase, syntactic phrase and so on. In the OT literature, there are several different theories of constraint structure: on the faithfulness side, there is a fair degree of consensus (McCarthy and Prince, 1995); on the structural side, there is rather more variation.

In addition, OT phonology has often been associated with views about the <u>source</u> of constraints. For the most part, these sources are seen as giving phonological constraints a 'functional grounding': sometimes implying, and sometimes explicitly asserting, that structural constraints are derived from phonetic facts about articulation or perception, cognitive facts about memory and salience, and other sources (for a somewhat early but comprehensive survey, see the readings in Hayes, Kirchner and Steriade, 2004).

To keep this textbook manageable in size, scope and narrative cohesion, it will side-step the debate over the source of structural constraints almost entirely. Our goal will be to capture production processes using constraints that have been proposed and found descriptively useful in the literature, but we will not have anything to say about how these unifying constraints relate to other mental or physical realities. This is not to suggest that the search for sources is not important! Once having absorbed something of the facts and their interpretation in this book, the reader may well be better equipped to delve deeper into their structure and provenance.

3.5.3 Comparing Frameworks: Constraints vs. Rules Part 1

Even with what little we have now seen of Optimality Theory, it is already useful to step back and compare its workings with the rule-based phonology that this text assumes you already know. To make the comparison concrete, we will contrast two analyses of a coda-less language in which /CVC/ and /CVCC/ → [CV]. In constraint-based terms, our understanding of this pattern is encoded in the following simple ranking:

(55) {NoCoda, Dep} >> Max

In a rule-based grammar, this pattern might instead be analysed with a simple rule:

(56) $C \rightarrow 0\ /\ \_\_]_{\sigma}$ (delete all syllable-final codas, one at a time)

The first point to emphasize is that rule-based grammars almost always apply in some *serial* fashion – one rule at a time, producing a series of intermediate strings along the way to final surface product – whereas a core component of OT is that every output candidate is considered at the same time, in *parallel*. Thus in mapping from for example /CVCC/ to [CV], there is no sense in which the grammar removes one member of the coda cluster 'before' the other. This turns out to have many ramifications, both helpful and challenging.

The second focus for now will be the relative emphasis on the *change* imposed by rules (variously also called the process, or the repair, terms used throughout this text) vs. the *targets*, which are the aims of structural constraints. The constraint-based view of grammar predicts that a single surface configuration will be resolved differently by different languages and children: onset clusters might be resolved via deletion, epenthesis and perhaps many other tricks. On the other hand, rule-based grammars instead focus on the processes of deletion, epenthesis and so on as the primary objects of study.

What's the difference? In one sense, the discomfort with a focus on process can simply be that rules without targets feel like they 'miss the point' – the <u>analyst</u> knows that the rule in (56) is 'about' avoiding codas, but the <u>grammar</u> knows nothing of this goal. But here is a more important issue: if processes are the primitives, what makes an attested or an unattested rule? In a constraint-based grammar, we expect consonants to be deleted at the ends of syllable and not the beginnings – because there is a constraint NoCoda, and there isn't a constraint NoOnset. What is the rule-based equivalent of this predictive power? What can rule out (57) compared to (56)?

(57): $C \rightarrow 0\ /\ _{\sigma}[\ \_\_$ (delete all syllable-initial onsets – **unattested**!)

It is not that restrictions on rules can't be written: see especially Selkirk (1982) and Ito (1986, 1989), in which string-based rules like (56) were replaced by rules for manipulating prosodic representations, along with principles for where and when to apply them. Rather, the argument is that the constraint-based approach is inherently made for seeing surface generalizations, and for capturing complicated 'conspiracies' via a simple(r) set of structural pressures, interleaved with faithfulness constraints in a strict ranking. The OT architecture thus provides a well-structured approach to analysing many disparate phenomena with a few tools – like the disparate phenomena of child and adult phonologies.

Before continuing, it might be worth emphasizing that this OT architecture also makes it much easier to directly build a theory of phonological acquisition – that is a method by which a learner could move from one constraint ranking to the next, until finally approximating the target language. This text's final chapter is an introduction to some such methods, and it will aim to connect much of the empirical work from these early chapters on child production data with results from the OT learnability literature.

3.6 Methodology: Longitudinal and Cross-Sectional Studies

To close this chapter, we will talk very briefly about the two most common ways that data on the development of phonological production has been collected: *longitudinal* and *cross-sectional* studies.

Longitudinal studies are about individuals' development over time. They typically follow a small group of children (very often just one, but sometimes a handful or even dozens), starting as early as the babbling stages but usually somewhere around the onset of productive speech, and recording phonological data at intervals, tracking the children's progress over months if not years. Often their goal is to accumulate enough data to evaluate overall phonological development within a small population, encompassing most aspects of the target language's phonology. Data collection usually occurs at least once a month, perhaps for an hour at a time, and often during a play session with favourite toys or storybooks, aimed at eliciting as much spontaneous speech from the child as possible. Some studies of a larger group might only collect data every six months, while those which focus on a single member of the researcher's own family (usually called '*diary studies*') might collect data nearly every day and thus in a much wider range of contexts. The earliest longitudinal data (beginning in the 19th century, and also during a renaissance in the 1960s and 1970s) was transcribed by the researcher straight to paper, as accurately as possible given perceptual and memory constraints. Today, data is usually collected via audio recording, with increasingly good sound quality (lapel mikes are a precious gift), and sometimes with simultaneous video as well.

In contrast, cross-sectional studies are in many ways less about depth and more about breadth. Typically, they focus on the acquisition of a particular structure or process, by gathering single-session data from a large group of children (sometimes into the hundreds of participants) at a pre-chosen stage of development, usually in a specific age range, but also for example with a certain vocabulary size and so on. The session often includes semi-structured tasks or games, asking children to name objects or describe pictures designed to elicit the phonological structures of interest. The goal of many cross-sectional studies is to establish normative, age-related milestones (e.g. by what age does the average typically-developing English-speaking child acquire complex onsets?), and to infer the relative order of acquisition among structures (under the assumption that e.g. if more two year olds produce complex onsets accurately compared to complex codas, then complex onsets must be acquired earlier). The data published from cross-sectional studies is often aggregated in multiple ways, collapsing across items, children or both, and provides sufficient power for statistical comparisons between groups and conditions.

It is hopefully already clear that both longitudinal and cross-sectional studies are necessary to form meaningful generalizations about the acquisition of phonology, or indeed any linguistic knowledge. Longitudinal studies provide the depth and detail to build individual grammars – they provided nearly all of the examples used in this chapter, and to a lesser extent in the ones to come, and they provide an invaluably comprehensive window on development. Especially in the case of diary studies, they can capture developmental stages that only last a few days, or processes unique to a subset of the lexicon (see Chapter 7) and they can be annotated with sufficient context to be sure of the inputs being attributed to the child. With very young children (e.g. below 16 months), these studies may be the only way to gather sufficient data for any kind of analysis at all: sporadic speakers, uncomfortable with strangers and uninterested in imitation tasks, may perhaps only be studied in a longitudinal setting.

On the other hand, cross-sectional studies provide the context to see how individual children fit into the spectrum of developmental possibilities. The age at which one child acquires a structure is fairly meaningless unless we know what other children do, or when learning other languages – especially since that structure's acquisition may be dependent on another aspect of their phonology, whose correlation would only be noticed after multiple children were observed doing the same thing. Cross-sectional data is almost always collected by an impartial observer, which affords less contextual knowledge but also introduces less bias. And while cross-sectional data may not allow in-depth coverage in some respects, its structured data collection may in fact gather more answers to a particular research question in one session than through months of spontaneous speech.

One of the tricky balancing acts for the linguist studying phonological acquisition is to use these two data sources in tandem. How much stock should we put in any one child's data? And then again, how should data averaged across multiple children be interpreted? These questions will become more crucial as we proceed, and as you consider your own interests in studying phonological development.

3.7 Further Reading

Readings on Optimality Theory – to Get Started

Gouskova, Maria. 2010. Optimality theory in phonology. In B. Heine and H. Narrog (eds) *The Oxford Handbook of Linguistic Analysis*. Oxford: Oxford University Press. 531–553.

McCarthy, John J. 2008a. *Doing Optimality Theory: Applying Theory to Data*. Malden, MA & Oxford: Wiley-Blackwell.

Classic OT Readings, Especially for References on Constraint Definitions

Prince, Alan and Smolensky, Paul. 1993. *Optimality Theory: Constraint Interaction in Generative Grammar.* Ms, Rutgers University & University of Colorado, Boulder. Published 2004, Malden, MA & Oxford: Blackwell.

McCarthy, John J. and Prince, Alan. 1993a. *Prosodic Morphology I: Constraint Interaction and Satisfaction*. Technical Report #3, Rutgers University Center for Cognitive Science, 1993.

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On the Development of Child Syllable Structure

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Exercises

Q1: One day, at age 2;1.14, Trevor produced the word 'straw' as [dɛwɔː]. *What do you think are the necessary components of a grammar that would produce such a mapping?* Draw a tableau with all the candidates you think need to be considered. Include only those constraints that are strictly relevant to choosing between those candidates. Comment on any difficulties you have in getting the winner to win. (You won't be able to predict vowel quality in any way – you might as well consider the mapping as from /strV/ → [dVwV].)

Q2: Examine the data below, from a child Joe at 4;6 whose phonological development was delayed. Comment on his treatment of word-initial [s]C clusters. *How many repairs does he have? How can you predict them?* You will need to talk about syllabification to understand the patterns. You don't have nearly enough constraint-based tools to capture these pattern as of yet, but try at least to write sufficiently-explicit rules to describe them.

Target	*Child*	*Target*	*Child*	*Target*	*Child*
skate	[ksejt]	*hospital*	[hɔspɪɾɫ]	*suspicious*	[səfɪʃəs]
skunk	[ksʌŋk]	*whisper*	[wɪspɹ]	*explain*	[flejn]
scar	[ksaɹ]	*icebox*	[ajspɔks]	*I spy*	[ajfaj]
spoon	[fuwn]	*mistake*	[mɪsteik]	*Scott's school*	[ksɔtsksuwɫ]
space	[fejs]	*upstairs*	[əpsɛɹz]	*boyscout*	[bɔjksæwt]
spinach	[fɪnɪtʃ]	*lipstick*	[lɪpsɪk]	*rollerskate*	[ɹowɫɹksejt]
stitch	[sɪtʃ]	*understand*	[əndɹsænd]	*telescope*	[tʰɛləksowp]
story	[sɔɹi]				
street	[sɹit]				

Q3: In tableaus (28) and (29), we looked at a grammar fragment that prefers vowel epenthesis over consonant deletion, to satisfy *COMPLEXONSET. But we did not give any account of *where* epenthesis takes place. Notice that either of the epenthesis mappings below satisfy the structural constraint!

	/spæm/	*ComplexOnset
a)	spæm	*
☞ b)	əs.pæm	
☞ c)	sə.pæm	

What constraints could choose between candidates (b) and (c)? In the data we analysed in this chapter, candidate (c) should win – however, candidate (b) is a very viable contender. Recall the connection between the English word *Spanish* and the Spanish word *Español?* Cross-lingusitically (and even among children) both epenthesis patterns are possible, so there must be constraints that prefer (b) over (c), too.

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Answers from table (52) (recall that tʃ is an affricate, and so does not violate *ComplexOnset)

(52)

	/tʃaɲklas/	*Syllable Contact	Max	*Complex Onset	NoCoda
a)	tʃaɲ.klas	*!		*	**
b)	tʃaɲ.kas	*!	*		**
☞ c)	tʃa.klas		*	*	*
d)	tʃa.kla		**!		