<u>AN OPTIMALITY THEORETIC ANALYSIS OF THE SOURCE AND PATTERNS OF PHONOLOGICAL OPACITY IN DEVELOPING GRAMMARS</u>

by

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An Optimality Theoretic Analysis of the Source and Patterns of Phonological Opacity in Developing Grammars

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

AN OPTIMALITY THEORETIC ANALYSIS OF THE SOURCE AND PATTERNS OF PHONOLOGICAL OPACITY IN DEVELOPING GRAMMARS

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This dissertation applies an Optimality Theory Candidate Chains (OT-CC: McCarthy 2007) analysis to transient opaque productions which appear during early L1-acquisition (Smith 1973; Velten 1943; Cho and Lee 2003; Ettlinger 2009; Barlow and Keare 2008) and argues that early child opacity differs in critical ways from the type of opacity that appears in mature grammars as well as from what is predicted to be possible by current theory. I show that these previously unpredicted patterns of opacity require the theoretical modifications of lifting the B » PREC(A, B) metaconstraint ranking and splitting the (a) and (b) PRECEDENCE clauses into individually rankable constraints (Wolf 2011). I further show that comparison of these early child opacity patterns to the temporary opacity which emerges during adult L2-acquisition (Eckman *et al*. 2003) and delayed child L1-acquisition (Dinnsen *et al*. 2000; Dinnsen *et al*. 2011) reveals that the early child patterns are distinct

from a general language acquisition effect. I argue rather that this opacity is a consequence of simultaneous versus sequential phonological process application during early L1-acquisition and is driven by a revised initial state of MARKEDNESS » PRECEDENCE » FAITHFULNESS; thus, it is limited to stages of early L1-acquisition and disappears after key re-rankings irreversibly alter default structure.

CHAPTER 1:
REPRESENTATION OF PHONOLOGICAL OPACITY

1.1. Introduction

The phenomenon of phonological opacity, in which surface forms fail to fully reflect underlying phonological processes, is challenging to any theory that focuses on output or attempts to describe the surface production. An example of an opaque phonological interaction can be seen in Tiberian Hebrew, where consonant clusters and /ʔ/ in coda position are ungrammatical, and the underlying form /deʃʔ/ surfaces as [deʃe]. This output satisfies the language generalizations, but is considered opaque since output *[deʃ] also satisfies them, making application of epenthesis appear unmotivated. Opacity has provided particular challenges to Optimality Theory (OT), a constraint-ranking framework where all possible output forms are evaluated in a single parallel optimization based on a language-specific ranking of universal constraints. Transparent phonological generalizations can be represented as a straightforward explanation of changes between the underlying form and the surface production, such as surface [tak] from underlying /tag/ for final coda devoicing in German, that are easily expressed in OT through specific constraint interactions. Opaque forms are notable exceptions to this in that they require either what appears to be a gratuitous constraint violation or a failure to satisfy a highly ranked constraint in favor of a lower ranked constraint. Such violations cannot be fully explained under a purely linear constraint ranking approach and require additional theoretic stipulations, such as some way to incorporate the interaction between the changes which have occurred. For instance, the opaque Tiberian Hebrew output is straightforwardly explained as a sequence of changes, such as /deʃʔ/ → [deʃeʔ] → [deʃe], but standard OT has no way to refer to the intermediate form. Attempts to account for opaque outputs have prompted important and theoretically diverse extensions to Optimality Theory. However, these representations require some level of theoretical abstraction away from the initial premises of OT regarding a parallel account of the set of changes between the underlying form and the surface production with simultaneous evaluation of all possible output forms. Some relatively successful theoretical extensions introduce ways to relate output candidates to forms other than the input, i.e., an intermediate form, which is fundamentally absent from the input-output evaluation of OT.

The inability to represent scenarios of over- or under-application of a process has been viewed as a crucial weakness for Optimality Theory; however, I argue that it is the very level of abstraction necessary to account for these scenarios which adds explanatory power to the theory. An OT theoretical extension such as Optimality Theory Candidate Chains (OT-CC), not only represents opaque interactions, but also makes typological predictions regarding the opacity patterns that can occur in natural language. OT-CC can also reveal previously overlooked distinctions between the phenomena of temporary early child acquisition opacity and the opacity found in mature grammars. For these reasons, I primarily focus on OT-CC representations of opaque productions during early child acquisition.

The remainder of chapter 1 will be organized in the following manner. In §1.2 and §1.3 I illustrate the four predominant types of phonological process interactions, transparent feeding and bleeding (Kiparsky 1968) and opaque counterfeeding and counterbleeding. I also briefly discuss the typology of opacity patterns. In §1.4 I discuss how a constraint-based approach provides an overall superior account of the majority of phonological generalizations and outline some of the major premises of Optimality Theory (OT). Although this section shows how constraint ranking effectively represents and explains ubiquitous transparent interactions such as feeding and bleeding, it also highlights a weakness for surface-based representations by showing how less common opaque interactions such as counterfeeding and counterbleeding fail under parallel evaluation. In §1.5 I outline the fundamental premises for a predominant theoretical expansion to OT, that of Optimality Theory Candidate Chains (OT-CC), and demonstrate how it successfully accounts for counterfeeding and counterbleeding scenarios. However, OT-CC formulations are designed to restrict the range of opaque interactions and Wolf (2011) suggests that this may be overly restrictive for natural language. In §1.6 I outline his proposed modifications to OT-CC which would allow it to account for a larger range of theoretically viable opaque interactions. I conclude in §1.7 by discussing the types of typological distinctions and predictions for opacity made by OT-CC. I also preliminarily discuss how, when applied to opaque productions in early child acquisition, OT-CC can reveal previously overlooked patterns of opacity. However, these patterns can only be fully represented and explained with modifications to OT-CC. The patterns of opacity found in early acquisition, and the corresponding implications for the initial state are the focus of this dissertation and discussion continue throughout chapters 2 through 5.

1.2. Phonological transparency

A phonological generalization is considered to be transparent when the underlying processes operating on the input are fully reflected in the surface form. Phonological transparency can be seen in processes such as Standard German final obstruent devoicing, where input /tag/ is output as /tak/ and Spanish intervocalic stop spirantization, where input /xwego/ is output [xweɣo]. Kiparsky (1968) identified two major types of transparent interactions, those of rule *feeding* and rule *bleeding*. Both types result in transparent surface forms, but differ in how many phonological processes can apply.

In a bleeding interaction, application of the first process *bleeds* the environment for application of the second process; thus, only one will apply. Kiparsky (1968) gives an example of bleeding in Alsatian German, which has the phonological processes of final obstruent devoicing (e.g., /tag/ → [tak] '*day*') and spirantization of voiced post-vocalic stops (e.g., /sagt/ → [saɣt] *3rd sg. 'says'* and /tagə/ → [taɣə] '*days*'). As illustrated in (1), devoicing bleeds the voicing required for spirantization in output [tak] by removing the voiced feature of the post-vocalic segment for input

/tag/. However, when the voiced obstruent is not word final, and therefore not in an environment where devoicing can apply, such as the morphologically altered forms /tagə/ and /sagt/, the post-vocalic stop is spirantized, as shown in (1).

(1)	Attested Alsatian bleeding ordering:	/tag/	/tagə/	/sagt/
	final obstruent devoicing	[tak]	n/a	n/a
	post-vocalic spirantization	n/a	[taɣə]	[saɣt]

Additionally, if the process order was reversed, as shown in (2), spirantization would fail to bleed the voice feature triggering devoicing and the resulting fricative would be devoiced in word final position, resulting in the ungrammatical feeding interaction of /tag/ → [taɣ] → *[tax].[1]

(2)	Unattested non-bleeding ordering:	/tag/	/tagə/	/sagt/
	post-vocalic spirantization	[taɣ]	[taɣə]	[saɣt]
	final obstruent devoicing	*[tax]	n/a	n/a

In a feeding interaction, application of one process *feeds* the environment for application of another; thus, both processes are transparently motivated and both

[1] While /tag/ → [tak] is the grammatical *bleeding* interaction output (and ordering) for Alsatian German (Kiparsky 1968), /tag/ → [taɣ] → [tax] is the grammatical *feeding* interaction output for other German dialects, including Low German (Kiparsky 1968; Lee 2009). However, the failure to bleed that would result from reversing the ordering of these processes in Alsatian German would technically be *counterbleeding*.

apply. Kiparsky (1971) claims that a feeding interaction is considered the least marked of the various types of process interactions. Kiparsky (1968) illustrates a feeding ordering with Finnish *intervocalic consonant deletion* (e.g., /teɣe/ → [tee])[2] and *diphthongization* (e.g., [tee] → [tie]). The ordering required for both processes to apply, and the one that results in the attested surface form, is illustrated in (3).

(3)	Attested feeding Finnish ordering:	/teɣe/
	intervocalic consonant deletion	[tee]
	diphthongization (ee > ie)	[tie]

If the ordering of these processes were reversed, intervocalic consonant deletion would fail to feed (i.e., block) diphthongization since at the time diphthongization can apply, consonant deletion has not yet created the necessary environment. This order would result in the ungrammatical surface form shown in (4).

(4)	Unattested non-feeding Finnish ordering:	/teɣe/
	diphthongization (ee > ie)	[teɣe]
	intervocalic consonant deletion	*[tee]

[2] This type of intervocalic consonant deletion, i.e., C → ∅ / V__V, applies to fricatives in the underlying representation. In Finnish, voiceless stops also become voiced fricatives of the same place, but these are (opaquely) not deleted.

As illustrated in (1) and (3), both bleeding and feeding interactions reflect the underlying phonological processes, as well as any necessary orderings, in the surface form. Moreover, since application of one can either feed (i.e., create) or bleed (i.e., destroy) the environment for the second, they are specifically defined interactions between two processes. In spite of the dependency for these types of interactions on order of application, the motivation for each individual process is still considered transparent in the output.

1.3. Phonological opacity

However, Kiparsky (1971) further observed that given a strict ordering of two specific processes, they will interact in two primary ways, either *transparently* or *opaquely*. As mentioned previously, a phonological generalization is considered to be opaque when the underlying processes operating on the input are not fully reflected in the surface form. Given two phonological processes, which individually apply transparently in the grammar, interaction between these processes results in a form where the application, or non-application of one of the processes is by no means obvious, i.e., opaque. This type of scenario can be illustrated with nasal place assimilation and word-final stop deletion after a homorganic nasal in Catalan (Mascaró 1976; Kiparsky 1985; Kenstowicz 1994). In (5) the nasal consonant /n/ assimilates to the place of articulation when followed by another consonant. Final (homorganic) stop deletion is transparent in (d) and grammatical nasal place agreement can be seen in the outputs for (b) and (e). However, in (c), the motivation for velar assimilation of the nasal is not obvious on the surface, so this form is considered opaque. Similarly, deletion of the final stop is also not obviously motivated in underlying /bɛnk/ since the stop is not homorganic with the nasal.

(5) Catalan nasal assimilation and final stop deletion

(a) /bɛn/ → [bɛn]	3rd sg. 'sell'	(d) /bint/ → [bin]	'twenty'
(b) /bɛns/ → [bɛns]	2nd sg. 'sell'	(e) /bintɛ/ → [bintɛ]	'twentieth'
(c) /bɛnk/ → [bɛŋ]	1st sg. 'sell'		

Kiparsky (1971) identified the two most predominant opaque phonological interactions as *counterbleeding* and *counterfeeding*. Counterbleeding occurs when application of one process *fails to bleed* the environment necessary for the application of another process and both processes apply. Counterfeeding occurs when application of one rule *fails to feed* a second rule and only one process applies. A more formalized definition of opacity comes from Kiparsky (1973), where given a phonological rule such as A→B/C__D, opacity manifests as a surface forms showing:

(i) A in the environment of C__D, or

(ii) B in some environment other than C__D

In line with Kiparsky's formalism, McCarthy (1999) describes opaque phonological processes as ones in which a generalization is not satisfied in the surface form and the rule itself appears unmotivated. He expanded upon Kiparsky's (1971, 1973) discussion of types of process interactions by proposing that opaque interactions fall into two broad classes; *over-application*, which includes counterbleeding interactions, and *under-application*, which includes counterfeeding interactions.

Following McCarthy, in a counterbleeding interaction, a process appears to *over-apply* and this results in a final form that is *non-surface-apparent*, i.e., the conditions which make a generalization applicable are not apparent on the surface. An example of counterbleeding opacity can be seen in the previously introduced Tiberian Hebrew scenario. This language has a process of ʔ-deletion everywhere but in onset position. Application of this process results in an underlying form such as /qaraʔ/ being produced as [qara] *'he called'*. This language also has a process of epenthesis which breaks up final consonant clusters. This process results in an underlying form such as /melk/ being produced as [melex] *'king'*.[3] As we saw earlier, there are also contexts in which these two processes interact on an input, such as the form /deʃʔ/, which contains both a non-onset /ʔ/ and a final consonant cluster. The output form in this case, [deʃe] *'tender grass,'* is considered opaque because application of ʔ-deletion should lead to the output form [deʃ]. This would in principle be a legitimate production for Tiberian Hebrew since it has neither a complex coda nor a /ʔ/ in non-onset position, but it is nevertheless unattested. The actual facts of the language are such that in the interaction of epenthesis and deletion, ʔ-deletion *fails to bleed*

[3] The continuance change for /k/ is ignored here since it is tangential to the process of epenthesis.

epenthesis because epenthesis applies first. As shown in (6), the actual output of [deʃe] can only be derived from this particular sequence of applying these processes.

(6) Attested Tiberian Hebrew order (counterbleeding):

epenthesis into consonant clusters	/deʃʔ/ → [deʃeʔ]
ʔ-deletion outside onsets	[deʃeʔ] → [deʃe]

Importantly, the *counterbleeding* order in (6) allows both epenthesis and ʔ-deletion to apply.[4] Conversely, application of ʔ-deletion first, as seen in (7), would remove, or *bleed*, the environment for epenthesis to occur.

(7) Unattested Tiberian Hebrew order (bleeding):

ʔ-deletion outside onsets	/deʃʔ/ → *[deʃ]
epenthesis into consonant clusters	*[deʃ] *(does not apply)*

With the order in (7), subsequent application of epenthesis, i.e., [deʃ] → [deʃe], is not motivated by the surface conditions since it no longer breaks up a consonant cluster. Consequently, epenthesis has the appearance of unmotivated, or seemingly

[4] For this particular counterbleeding scenario, the environment for application of either process first is available. However, another common counterbleeding scenario is one where application of one process actually creates the environment for a second process that could not have applied initially. This can be seen in the Catalan example in (5), where final (homorganic) stop deletion would not occur if not preceded by nasal assimilation in /bɛnk/ → [bɛŋk] → [bɛŋ].

gratuitous, application in [deʃe]. This *over-application* of epenthesis corresponds to the second type of opacity specified by Kiparsky.

For a counterfeeding interaction, again following McCarthy's terminology, a process appears to *under-apply* and this results in a final form that is *non-surface-true*, i.e., a generalization which plays an otherwise active role in the language is violated by some surface forms. An example of counterfeeding opacity can be seen in Bedouin Arabic (McCarthy 1999), which has a process of vowel raising of /a/ to [i] in open syllables. This process is highly productive and results, for example, in underlying /ka.tab/ being produced as [ki.tab] *'he wrote'*. Similar to Tiberian Hebrew, Bedouin Arabic also has a process of vowel epenthesis which breaks up complex coda clusters. In an underlying form like /gabr/, epenthesis applies to give the output form [ga.bur] *'grave'.* However, in spite of the /a/ being in an open syllable on the surface, vowel raising does not apply and the output form *[gi.bur] is unattested. The form [ga.bur] is thus considered opaque because it appears to violate /a/ raising in an open syllable. To derive the attested output form [ga.bur], the processes must be applied in the order specified in (8). Here epenthesis *fails to feed* vowel raising since the latter applies first.

(8) Attested Bedouin Arabic rule ordering (counterfeeding):

vowel raising in open syllables	/gabr/ *(doesn't apply)*
epenthesis of [u] in complex codas	/gabr/ → [gabur]

However, the reverse order specified in (9) is a *feeding* interaction, where both epenthesis and vowel raising are structurally motivated, resulting in *[gibur].

(9) Unattested Bedouin Arabic rule ordering (feeding):

epenthesis of [u] in complex codas	/gabr/ → [gabur]
vowel raising in open syllables	[gabur] → *[gibur]

We can see that it is the *counterfeeding* order in (8) itself that blocks application of vowel raising in the derived environment—which otherwise appears to be merited by the surface conditions—so that only epenthesis applies. This *under-application* of vowel raising corresponds to the first type of opacity specified by Kiparsky.

While the majority of phonological opacity scenarios fall under counterbleeding or counterfeeding patterns, there is a range of additional forms of phonological opacity. An incomplete list of alternative forms includes opaque feeding (Lee 2007), mutual bleeding (Itô and Mester 2003) and obligatory counterbleeding (Wolf 2008, Ettlinger 2008). Baković (2007) also defines three types of over-application opacity in addition to counterbleeding: self-destructive feeding, nongratuitous feeding and cross-derivational feeding.[5] However, due to their predominance, counterfeeding and counterbleeding opacity patterns continue to receive the majority of the focus in opacity literature (Kiparsky 1971, 1973, 2000; Benua 1997; McCarthy 1999,

[5] I analyze these additional opacity patterns under OT-CC as part of a look at the treatment and typological frequency of documented natural language opacity types (Waybright, forthcoming).

2002, 2003, 2007; Goldrick and Smolensky 1999; Goldrick 2001; Moreton and Smolensky 2002; Itô and Mester 2003; Lubowicz 2003; among many others).

Although counterfeeding and counterbleeding opacity often receive roughly equivalent status in the opacity literature, they are not necessarily equivalent typologically. According to Ettlinger (2008), there are gaps in the typology; counterfeeding appears to be a quite common process while counterbleeding is rare. In a survey of 13 languages, Ettlinger (2008) specifically looks at phonological processes that potentially interact with vowel or consonant harmony and among such interactions he finds four counterbleeding processes and nine counterfeeding processes.[6] Ettlinger further observes that while all nine counterfeeding scenarios create environments for harmony, there is only one case of counterbleeding triggering harmony. The rarity of the latter type of scenario suggests that such interactions may be more structurally marked in terms of the types of underlying to surface phonological changes.[7] Greater structural markedness would in turn provide additional justification for the overall rarity of counterbleeding interactions. If feeding is the least marked (Kiparsky 1971), and presumably most frequent form

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[6] Although Ettlinger's focus is on harmony, he considers this unequal ratio of counterbleeding and counterfeeding processes to be generally representative of the ratio for phonological processes. The counterbleeding processes discussed in Ettlinger (2008) include Yakuts epenthesis, Shimakonde reduction, West Greenlandic epenthesis/deletion (Cearley 1976) and Canadian French pre-fricative tensing (Poliquin 2007). The counterfeeding processes include Mafa epenthesis, Maltese shortening (Puech 1978), Armenian epenthesis (Vaux 1998), Mafa assimilation, Yokuts lowering, Shimakonde coalescence, Icelandic epenthesis, Kalong tensing (Hyman 2002) and Sea Dayak deletion (Kenstowicz and Kisseberth 1979).

[7] Ettlinger looks at how these interactions are analyzed under a rule-based approach. However, rule ordering itself does not make predictions regarding markedness or potential frequency.

of process interaction, then the greater frequency of counterfeeding, as the counterfactual inverse of feeding, may also correspond to being a less marked form.

Ettlinger's (2008) findings on greater frequency of counterfeeding interactions (i.e. more than twice the number of counterbleeding interactions) closely parallels the findings of an on-going survey of the typological frequency of patterns of natural language opacity (Waybright, forthcoming).[8] Preliminary results suggest that counterfeeding interactions occur more than twice as frequently as counterbleeding. It is also possible that general typological gaps between over- and under-application opacity may be expanded through pattern cross-over. Baković (2007) claims that even some types of over-application opacity are the result of a type of feeding rather than bleeding interaction, thus further biasing overall opaque interaction types toward some form of feeding interactions. However, it is sufficient at this point to establish that there at least appears to be a typological bias toward counterfeeding opacity. I return to more in-depth discussion of how typological frequency corresponds to predictions under particular theoretical representations.

1.4. Optimality Theory (OT)

Early work on defining the primary types of phonological interactions (Kiparsky 1968, 1971, 1973) occurred under derivational (i.e., rule-based) approaches, which focus on a series of changes from the underlying representation to the surface form

[8] A compilation of documented natural language opacity comes from sources such as Kager (1999); Kenstowicz & Kisseberth (1979); McCarthy (1999, 2007); Ettlinger (2008); Moreton (2010); Baković (2011); Wolf (2011); among others.

and express generalizations as a series of re-write rules. However, Hayes (1999) observed that these concise explanations of language-specific alternations were ultimately problematic for derivational approaches because they emphasized language-particular derivations as the central element of the theory rather than extending them to universal language patterns.[9] Derivational approaches eventually began to lose favor in comparison with surface-based approaches in what Baković (2011) describes as the field's "massive (but incomplete) shift" from rule-based *serialism* to a constraint-based *parallelism*. Instead of positing individual rules to account for an alternation, a violatable constraint ranking representation shifted the focus to larger principles governing conspiracies and markedness. This type of representation treats well-formedness as the fundamental problem of phonology and leaves the problem of alternation in the background. (See early discussion of constraints in lieu of rules to define grammars in Postal (1968) and Scobbie (1997).)

Optimality Theory (Prince and Smolensky 1993/2004), the current dominant constraint-based theory of phonology, focuses on the overall harmony (i.e., structural well-formedness) of interacting processes by expressing generalizations via relative constraint rankings. In an OT framework, the output, or surface representation is selected from multiple competing candidates based on how these

[9] Early motivation for moving away from derivational approaches came from problems such as the failure of rule-based conspiracies, where distinct sets of rules acting within a language, or even across languages, conspire to target and eliminate particular marked structures. However, reliance on language specific rule orderings and representations resulted in failure to establish an isomorphic relationship between language specific alternations and generalizations across languages (Kissberth 1970; Kenstowicz & Kisseberth 1977; McCarthy 2003; Ettlinger 2008). A related subset problem was where the rule driving morphophonological alternations duplicated a required constraint on morpheme structure (see Topping 1969; Onn 1980; Herbert 1986; Teoh 1988; Pater 1999, 2004).

candidates satisfy a set of universal constraints. These constraints are strictly ranked and minimally violable, in the sense that constraints with a lower ranking can be violated only when doing so satisfies a higher ranked constraint. Such constraint rankings are represented in a hierarchy, generally seen as a linear representation, i.e., CONST1 » CONST2 » CONST3, and are interpreted as a decisive constraint dominance where CONST1 outranks both CONST2 and CONST3 and CONST2 outranks CONST3.[10] The set of possible outputs are compared to the input, or the underlying representation, and evaluated simultaneously (in parallel) with respect to the changes to the input. The winning candidate, or optimal output, is the most *harmonic* one in the sense that it incurs the fewest and least crucial violations of the highest ranked constraints, but it can still violate some lower ranked constraints.

Within standard OT, constraints typically fall within two broad categories, termed MARKEDNESS and FAITHFULNESS. MARKEDNESS constraints are also called *structural harmony* constraints since they involve language well-formedness. It is this set of constraints that acts upon the input to ensure the output is viable within a given language by assigning violation marks to less preferred structures and motivating changes to the underlying form. FAITHFULNESS constraints preserve the structure of the input by assigning violation marks where the input and output differ in some specific dimension, thereby restricting the types of changes are that allowed. Ultimately, it is competition between MARKEDNESS and FAITHFULNESS constraints which determines the optimality of a given output form.

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[10] Although see Bermúdez-Otero (1999, 2003) and Kiparsky (2000) for discussion of Stratal OT.

These sets of language constraints are inherently universal and differ between languages only in terms of how the constraints are ranked relative to each other. This allows typologies to be straightforwardly represented; they fall out from the set of all possible rankings and reveal biases for rankings of specific MARKEDNESS constraints.[11] Since the phonological system of a given language is formed from a unique ranking of these constraints, it also permits language-specific preferences in terms of what defines an optimal output form.[12] The significance of each individual MARKEDNESS constraint, and its ability to regulate surface representations, is determined by the ranking it receives relative all other constraints for a given language. The activity of a MARKEDNESS constraint in a ranking hierarchy is controlled both through conflict with opposing FAITHFULNESS constraints and competition with higher ranked MARKEDNESS constraints. Thus, within OT phonological generalizations are expressed as specific ranking of MARKEDNESS constraints with their conflicting FAITHFULNESS counterparts.

Another important aspect of standard OT (Prince and Smolensky 1993/2004) is how the output candidates are represented. Under a purely constraint-based theory of phonology, where input-output assessments occur in parallel, there is no step-by-step derivation, and thus no intermediate evaluation stages. Each candidate is a

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[11] This stands in contrast to derivational approaches where the precise form of the rules needed to be tailored in unique ways in order to capture complex language patterns, thus resulting in language-specific rules that failed to coalesce into universal language patterns.

[12] *Richness of the base* (Prince and Smolensky 1993/2004; Smolensky 1996) presumes that there are no language specific restrictions on the input.

direct mapping from the input to the final output with no intermediate form.[13] Rather, it is solely the final assessment of the constraint hierarchy that determines what changes create a well-formed output and candidates can only be assessed through language wide generalizations. Importantly, such a system has no means of allowing processes to be sequenced in order to trigger what appears to be over-application or block what appears to be under-application. However, transparent interactions, such as those resulting in feeding or bleeding patterns, do not require any sort of special stipulation within constraint ranking hierarchies.

1.4.1. Transparent scenario representations

To see how bleeding—a transparent interaction—is represented in OT, we can return to the Alsatian German scenario introduced in §1.2. Recall that the relevant processes are obstruent de-voicing in word-final coda position (i.e., /ta**g**/ → [ta**k**]) and post-vocalic spirantization of voiced stops (i.e., /ta**g**ə/ → [ta**ɣ**ə] and /sa**g**t/ → [sa**ɣ**t]). Therefore, the optimization will crucially involve the two MARKEDNESS constraints in (10).

(10) Relevant MARKEDNESS constraints:

a. SPIR: assign one violation mark for every voiced post-vocalic stop

b. *C[+VOI]#: assign one violation mark for every final voiced obstruent coda

[13] However, Prince and Smolensky (1993) discuss early possibilities for Harmonic Serialism.

These MARKEDNESS constraints are in direct conflict with a set of FAITHFULNESS constraints from the IDENT family: ID[VOI] and ID[CONT], formally defined in (11)a and (11)b. Given these constraints alone, a possible optimal output for a input form with a word-final voiced obstruent would involve vowel epenthesis after this obstruent (thereby removing the environment for de-voicing).[14] Thus a third FAITHFULNESS constraint restricting epenthesis is needed: DEP, defined in (11)c.

(11) Relevant FAITHFULNESS constraints:

a. ID[VOI]: assign one violation mark for every set of corresponding input-output segments which have different values for the feature [VOI]
b. ID[CONT]: assign one violation mark for every set of corresponding input-output segments which have different values for the feature [CONT]
c. DEP: assign one violation mark for every output segment which does not have a corresponding segment in the input

The interaction of these constraints is determined by their relative ranking. For the input form /tag/, the grammatical output is [tak], therefore *C[+VOI]# must outrank ID[VOI], since this FAITHFULNESS constraint is violated in order to satisfy the MARKEDNESS constraint *C[+VOI]#. Additionally, DEP must outrank ID[VOI] since epenthesis, which would allow the word final coda to re-syllabify as an onset, is not

[14] This type of epenthetic environment change to the input form is distinct from the morphologically driven environment change represented by an input such as /tagə/, where /ə/ is not epenthetic.

a grammatical solution in the language.[15] Similarly, for the input form /tagə/, the grammatical output is [taɣə]; therefore, SPIR must outrank the violated ID[CONT].

There is no direct evidence in these data to support the relative ranking of either *C[+VOI]# and SPIR or ID[VOI] and ID[CONT]. However, in general, OT assumes a default MARKEDNESS » FAITHFULNESS ranking.[16] This stems from research on learnability which argues that certain classes of constraints must be biased toward this ranking in order to result in sufficiently restrictive final-state grammars (Demuth 1995; Gnandesikan 1995, 2004; Pater 1997; Smolensky 1996; Jusczyk, Smolensky and Allocco 2002). Assuming general MARKEDNESS over FAITHFULNESS to permit changes between underlying and surface forms, the ranking needed to derive [tak] from underlying /tag/ is illustrated in (12).

(12) Tableau selecting devoiced coda segment

/tag/	*C[+VOI]#	SPIR	DEP	ID[VOI]	ID[CONT]
a [tag]	*!	*			
b ☞ [tak]				*	
c [taɣ]	*!				*
d [tax]				*	*!
e [tagə]		*	*!		

15 A similar argument could be made for MAX. However, I only specifically include DEP in (12) to contrast morphological environment changes with syllable structure changes in (13).

16 While the default MARKEDNESS » FAITHFULNESS ranking moves toward a FAITHFULNESS » MARKEDNESS ranking during language acquisition, specific MARKEDNESS » FAITHFULNESS ranking are still necessary for the grammar to allow changes between underlying and surface forms.

We can see in the tableau that the ranking of *C[+VOI]# over the faithful IDENT constraints eliminates output candidates (a) and (c). A violation of *C[+VOI]# is considered fatal here—indeed no other constraints outrank it in this optimization—and is marked with *!. Similarly, ranking DEP over the IDENT constraints eliminates candidate (e). Candidate (d) violates both FAITHFULNESS constraints, and is thus less optimal than candidate (b), which only violates ID[VOI]. Candidate (b) is the optimal candidate because it satisfies the higher ranked constraints and minimally violates the lower ranked constraints. Selection of this winning output is indicated by ☞.

Since both devoicing and spirantization occur in Alsatian German, the ranking in (12) must also select the correct output when the input contains a post-vocalic voiced stop, as illustrated in (13). The voiced stop is not word-final in input /tagə/, so *C[+VOI]# is inactive in this tableau and it is the high ranking of SPIR that eliminates the completely faithful candidate (a). However, the outputs [takə] and [taɣə] both satisfy SPIR. Thus, in order to allow the grammar to choose the grammatical output of [taɣə], we need to refine the constraint ranking with an additional relative ranking of ID[VOI] over ID[CONT].[17] Importantly, this revised ranking has no effect on candidate selection for word-final obstruent devoicing. Now, devoicing a stop in onset position, as in candidate (b), is ruled out by ID[VOI] and the optimal candidate is (c).

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[17] Candidates created by deletion of the final vowel are presumed to be ruled out by a high ranking of the FAITHFULNESS constraint restricting deletion, MAX. Additionally, the set of possible output candidates created by deletion would be subject to the same elimination process as those in (12).

(13) Tableau selecting post-vocalic spirantization candidate

/tagə/	*C[+VOI]#	SPIR	DEP	ID[VOI]	ID[CONT]
a [tagə]		*!			
b [takə]				*!	
c ☞[taɣə]					*

To see how feeding—also a transparent interaction—is represented in OT, we can return to the Finnish scenario introduced in §1.2. Recall that in this case the relevant processes are intervocalic fricative deletion (i.e., /teɣe/ → [tee]) and diphthongization (i.e., [tee] → [tie]). Therefore, the optimization will crucially involve the two MARKEDNESS constraints in (14).

(14) Relevant MARKEDNESS constraints:

a. *VCV: assign one violation mark for every intervocalic consonant
b. *HIATUS-RAISING[18]: assign one violation mark for every sequence of vowels where V_1 matches V_2 in the feature [HIGH] (raise height of V_1)

These constraints are in direct conflict with the FAITHFULNESS constraints ID[HIGH], defined in (15)a, and MAX. In order to preserve a distinction between consonant deletion and vowel deletion, MAX can be split into MAX-V and MAX-C, as defined in (15)b and (15)c.

[18] This constraint was proposed by Kirchner (1996) to analyze vowel raising in Western Basque, where mid vowels and high vowels that precede another vowel are raised by one degree and was initially defined as HIATUS-RAISING: In V_1 and V_2, maximize height of V_1.

(15) Relevant FAITHFULNESS constraints:

a. ID[HIGH]: assign one violation mark for every set of corresponding input-output segments which have different values for the feature [HIGH]

b. MAX-C: assign one violation mark for every consonant input segment which does not have a corresponding segment in the output

c. MAX-V: assign one violation mark for every vowel input segment which does not have a corresponding segment in the output

The interaction of these constraints is also determined by their relative ranking. For the input /teɣe/, both changes act on this form and the grammatical output is [tie]. Therefore *VCV must outrank MAX-C to motivate intervocalic consonant deletion (i.e., /teɣe/ → [tee]) and *HIATUS-RAISING must outrank ID[HIGH] to motivate diphthongization (i.e., [tee] → [tie]). Additionally, MAX-V must outrank MAX-C since final vowel deletion, which would remove the ungrammatical intervocalic consonant sequence, is not a grammatical solution. There is no direct evidence in these data for a relative ranking between either the MARKEDNESS constraints *VCV and *HIATUS-RAISING or the FAITHFULNESS constraints MAX-C and ID[HIGH]. Again a general MARKEDNESS over FAITHFULNESS format in (16) permits changes between underlying and surface forms and gives us the ranking needed to derive [tie] from underlying /teɣe/.

(16) Tableau selecting feeding interaction between diphthongization and deletion

/teɣe/	*VCV	*HIATUS-RAISING	MAX-V	ID[HIGH]	MAX-C
a [teɣe]	*!				
b [tee]		*!			*
c ☞ [tie]				*	*
d [teɣ]			*!		

We can see in this tableau that ranking of *VCV over MAX-C eliminates output candidate (a) and ranking *HIATUS-RAISING over ID[HIGH] eliminates candidate (b). Similarly, ranking MAX-V over MAX-C eliminates candidate (d). While candidate (c) violates both ID[HIGH] and MAX-C, it is still the optimal output since it satisfies all higher ranked constraints.

1.4.2. Problems with opaque scenarios

While OT's focus on well-formedness provides a superior account of language generalizations, this focus is not entirely unproblematic since it can leave behind what Kiparsky termed a *derivational residue*—a set of unaccountable phenomena—for cases that do not smoothly emerge from rankings of constraints. Two significant patterns of alternation which leave a residue are the opaque interactions of counterbleeding and counterfeeding (Kiparsky 1973) and representation of these interactions is problematic for any constraint-based theory. As such, these interactions have proven a challenge to Optimality Theory where the relative harmony of all output candidates is evaluated in a single parallel optimization, without any intermediate forms. In the case of transparent generalizations—expressed through MARKEDNESS constraints regulating surface harmony—the optimal candidate is always the one that avoids marked structures while violating the least highly ranked FAITHFULNESS constraints. On the other hand, opaque generalizations can be thought of as involving violations to FAITHFULNESS constraints which do not appear to be motivated by improvements to surface structural harmony. We can see how standard OT fails to account for opacity in the following representations of the previously introduced examples of counterbleeding in Tiberian Hebrew and counterfeeding in Bedouin Arabic.

Recall that Tiberian Hebrew has the phonological processes of ʔ-deletion anywhere but onset position and epenthesis to break up consonant clusters. For an input form like /deʃʔ/, the grammatical output is [deʃe], where epenthesis appears to over-apply, since the conditions which trigger it are not evident on the surface (i.e., application of ʔ-deletion counterbleeds, or fails to bleed, epenthesis). The MARKEDNESS constraints which motivate epenthesis and ʔ-deletion are given in (17)(a-b), and the conflicting FAITHFULNESS constraints are given in (17)(c-d).

(17) Relevant MARKEDNESS and FAITHFULNESS[19] constraints:

a. CODA-COND: assign one violation mark for every /ʔ/ not in syllable onset

b. *COMPLEX: assign one violation mark for every consonant cluster

[19] While MAX-C and DEP-V are more specific than strictly necessary at this point, distinguishing consonant deletion and vowel epenthesis becomes relevant at a later stage.

c. MAX-C: assign one violation mark for every consonant input segment which does not have a corresponding segment in the output

d. DEP-V: assign one violation mark for every output vowel segment which does not have a corresponding vowel segment in the input

Minimally, the following relative rankings are necessary. Deletion of /ʔ/ from coda positions implies a ranking of CODA-COND » MAX-C. Consonant clusters broken up with epenthesis implies a ranking of *COMPLEX » DEP-V. There is no evidence for rankings between CODA-COND and *COMPLEX or MAX-C and DEP-V. The general MARKEDNESS over FAITHFULNESS ranking in (18) is consistent with these processes.

(18) CODA-COND, *COMPLEX » MAX-C, DEP-V

However, the ranking in (18) selects [deʃ] as the optimal candidate, as illustrated in (19), and no permutation of these constraints consistent with the necessary MARKEDNESS » FAITHFULNESS rankings will select the actual output [deʃe] since it receives what appears to be a gratuitous DEP-V violation.[20] Following McCarthy (2007), the optimal, but incorrect, candidate under this ranking is indicated by ☜, while the correct output (which is not selected by this ranking) is indicated by →.

[20] The additional epenthesis violation creates a superset of FAITHFULNESS violations for [deʃe] making it impossible for this set of constraints to favor it over [deʃ].

(19) Tableau selecting incorrect (transparently formed) candidate

/deʃʔ/	CODA-COND	*COMPLEX	MAX-C	DEP-V
a [deʃʔ]	*!	*		
b ☜[deʃ]			*	
c [deʃeʔ]	*!			*
d →[deʃe]			*	*!

At this point, it is not even significant that DEP-V must be ranked below *COMPLEX in order to allow the general process of breaking up consonant clusters since the only other candidate that obeys *COMPLEX, [deʃ], has a subset of the violations for the candidate [deʃe]. Since [deʃe] is harmonically bound by [deʃ], [deʃe] will lose regardless of how the constraints are ranked.[21] Application of one process appears to result in a well-formed output, so application of the second process appears to apply gratuitously given the environment. Consequently, standard OT fails to represent this counterbleeding interaction in Tiberian Hebrew.

Counterfeeding opacity, of course, has a different kind of failure in that OT must now block the type of feeding that fell out naturally in §1.4.1. Recall that Bedouin Arabic has the phonological processes of vowel raising in open syllables and epenthesis to break up consonant clusters. For an input form like /gabr/, the grammatical output is [ga.bur], where vowel raising appears to under-apply in the (otherwise appropriate) environment and the conditions which fail to trigger it are

[21] Candidate Y can be said to be harmonically bound by candidate X under a particular constraint set if candidate X has a proper subset of candidate Y's violation marks within a violation tableau. In this scenario, candidate Y cannot beat candidate X under any ranking of the constraints in the tableau.

not evident on the surface. The MARKEDNESS constraints which motivate vowel raising and epenthesis are given in (20)(a-b), and the conflicting FAITHFULNESS constraints are given in (20)(c-d).

(20) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. *COMPLEX: assign one violation mark for every consonant cluster
b. **a*CV: assign one violation mark for every /a/ in an open syllable
c. ID[LOW]: assign one violation mark for every set of corresponding input-output segments which have different values for the feature [LOW]
d. DEP: assign one violation mark for every output segment which does not have a corresponding segment in the input

Minimally, the following relative constraint rankings are necessary. The productive vowel raising pattern of /ka.tab/ → [ki.tab] in Bedouin Arabic implies a ranking of **a*CV » ID[LOW]. Consonant clusters broken up with epenthesis implies a ranking of *COMPLEX » DEP. There is no evidence at this point for ranking between **a*CV and DEP or *COMPLEX and ID[LOW]. An overall ranking that is consistent with these phonological changes is given in (21).[22]

(21) *COMPLEX » DEP, **a*CV » ID[LOW]

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[22] This ranking does not follow a general MARKEDNESS over FAITHFULNESS assumption since there is evidence of a transitive ranking of DEP » **a*CV during the OT-CC resolution to this opacity in §1.5.2.

While this ranking selects the highly productive vowel raising form [ki.tab] as optimal, it also selects the transparent, but unattested candidate [gi.bur] in (22).

(22) Tableau selecting transparent candidate (but not opaque candidate)

/ka.tab/	*COMPLEX	DEP	*aCV	ID[LOW]
a [ka.tab]			*!	
b ☞[ki.tab]				*
/gabr/				
a [gabr]	*!			
b →[ga.bur]		*	*!	
c ☜[gi.bur]		*		*

No possible permutation of these MARKENESS and FAITHFULNESS constraints will select the correct output form [ga.bur] while still selecting the correct (transparent) output [ki.tab]. As illustrated in (23), a ranking of ID[LOW] above *aCV would prefer [ga.bur] over *[gi.bur], but this ranking must simultaneously prefer *[ka.tab] over [ki.tab] since it restricts vowel raising in general. Additionally, we can see from (22) and (23) that in counterfeeding opacity, the ranking conflict with the opaque scenario only appears in conjunction with the required ranking for the transparent scenario. A successful constraint ranking is certainly possible for each individual case when considered in isolation, as seen in the correct transparent output selection in (22) and the correct opaque output selection in (23). Only when both forms must be evaluated does the ranking paradox become visible.

(23) Tableau for successful opaque output (but failed transparent output)

/ka.tab/	*COMPLEX	DEP	ID[LOW]	*aCV
a ☜[ka.tab]				*
b →[ki.tab]			*!	
/gabr/				
a [gabr]	*!			
b ☞[ga.bur]		*		*
c [gi.bur]		*	*!	

At this point we can see that in addition to failing to represent a counterbleeding interaction, standard OT has also failed to represent a counterfeeding interaction in Bedouin Arabic. Here, a process fails to apply in an environment where it otherwise should and thus appears to fail to generate a well-formed output. The failure of standard OT to account for these instances of under-application and over-application implies that it must be enriched in some way to account for both.[23]

[23] While counterbleeding invariably fails under a standard OT analysis, Baković (2007) claims that not all forms of over-application opacity fail under a parallel constraint evaluation. He demonstrates a successful standard OT representation for the over-application opacity forms of *nongratuitous feeding* and *cross-derivational feeding*. (See Baković (2007) for further detail on why these opacity patterns are best described as over-application and how they are represented under standard OT.) He further points out that there is an incomplete asymmetry regarding opaque productions and that some types of generalization obscurities are a consequence of the way generalizations are expressed in derivational or constraint-based frameworks, i.e., rules which interact through ordered sequences predict different types of obscure outputs than constraints in relative rankings. Furthermore, some attested types of obscured generalizations will fail under rule ordering representations while other attested types will fail under constraint ranking representations.

1.5. Optimality Theoretic approaches to phonological opacity

Critics of OT (Dresher 1996; Hale & Reiss 2008; Halle 1995; Idsardi 2000, 2006; among others) have used its failure to predict (and consequently represent) under- and over-application interactions such as counterfeeding and counterbleeding to claim that OT is not a viable phonological theory. However, immediately following its introduction by Prince and Smolensky (1993), myriad theoretical extensions to OT have been proposed as possible solutions to the problem of opacity. Attempts to address the types of *derivational residue* which emerge from a constraint ranking system included Derivational OT (Prince and Smolensky 1993; Kiparsky 1997), Output-Output Correspondence (Benua 1995, 1997; Burzio 1994; Hale *et al*. 1998), Paradigm Uniformity (Kenstowicz 1994), Local Constraint Conjunction (Smolensky 1995; Moreton and Smolensky 2002), Turbid representations (Goldrick and Smolensky 1999; Goldrick 2001), allomorph listing (Sanders 2003), Stratal OT (Bermúdez-Otero 1999, 2003; Kiparsky 2000), Targeted Constraints (Wilson 2001), Sympathy (McCarthy 1999), Comparative Markedness (McCarthy 2003), Candidate Chains (McCarthy 2006) and Harmonic Serialism (McCarthy 2010). Many of these solutions expand CON by introducing constraint classes beyond those of FAITHFULLNESS and MARKEDNESS. Some of these proposals account for only limited types of derivational residue (i.e., either counterfeeding or counterbleeding, but not both), and the majority of them tend to perform better with either over-application or under-application opacity. While few of these approaches provide a complete solution to opacity in OT, some have applications beyond opaque interactions and have thus become more firmly established in the mainstream version of the theory.

1.5.1. Optimality Theory Candidate Chains

The extension to OT of primary interest for this dissertation is McCarthy's (2007) Optimality-Theoretic Candidate Chains (OT-CC), which was initially proposed as a way to limit various types of over-generation in natural language. The appeal of OT-CC relative to other accounts of opacity under OT lies in its ability to uniformly represent both over- and under-application opacity.[24] This is largely achieved by providing the theory with a mechanism with which to track the succession of harmonic changes to output candidates, that of *Harmonic Serialism* (McCarthy 2006, 2007, 2010). Standard OT represents outputs as a single form, so one important difference between OT-CC and standard OT is in terms of what constitutes an output candidate. Harmonic Serialism allows the candidate generating function GEN to produce chains of incremental phonological changes as outputs. Thus under this approach candidates are gradual, one-step-at-a-time mappings from the input form to the final output form. The possible changes at any given step are highly constrained and, according to McCarthy, well-formed candidate chains are subject to the three universal conditions in (24).

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[24] The majority of opacity analysis in this dissertation is done with OT-CC, but I return to a comparison of child opacity under additional theoretical extensions in chapter 5.

(24) Conditions for Harmonic Serialism

a. *Gradualness:* Each form in the chain may differ from the previous one only by the performing of a single localized unfaithful mapping.

b. *Harmonic improvement*: Each form in the chain must be more harmonic than the previous one, given the prevailing language constraint hierarchy.

c. *Local Optimality*: Let $<\ldots f_{n-1}, f_n>$ be a valid chain in some language L. Let $g_1, \ldots g_m$ be all of the forms which can be formed from f_n by applying some localised (sic) unfaithful mapping (LUM) of the same type T. The chain $<\ldots f_{n-1}, f_n, g_i>$ is then a valid chain in L iff: (a) g_i is more harmonic than f_n, and (b) g_i is the most harmonic member of the set $\{g_1, \ldots g_m\}$.

These conditions can be reformulated more informally in the following way: starting with any valid input or subchain, GEN can only pursue the best way of making some type of change to this subchain. Therefore, in candidate chain formation, the first member of the chain must be fully faithful, each new form can differ from the previous form only by one FAITHFULNESS violation in a specific location in a form, and every change must be harmonically improving based on a given constraint hierarchy.[25] Essentially, the output of each optimization is resubmitted to GEN as the input for a possible new optimization. Each candidate

[25] According to McCarthy (2007) it is this requirement for harmonic improvement on "intermediate forms" that crucially distinguishes OT-CC from rule-based serialism and other serial versions of OT.

loops through GEN and EVAL until it converges on a form where further changes are not harmonically improving, i.e., it is fully faithful relative to the current input.

Therefore, another difference between standard OT and OT-CC, and one which appears to give OT-CC an acquisition advantage over standard OT, is in terms of restrictions on the number of possible output candidates. In standard OT, GEN produces an infinite set of possible outputs; however, harmonic improvement imposes a natural upward bound for the set of possible output candidates under OT-CC.[26] Thus the set of outputs for OT-CC is not only finite, but also fairly small. Such a restricted set of candidates for output evaluation is attractive from an acquisition perspective since it would be expected to decrease computational complexity.

Another significant change introduced to standard OT in OT-CC is a new class of constraints in CON known as PRECEDENCE (PREC) constraints. In order to allow opaque candidate chains to win over transparent ones, McCarthy (2007) suggested an augmentation to the standard classes of MARKEDNESS and FAITHFULNESS constraints with an additional class of constraints that evaluates the order in which changes, or processes, could occur within the chains themselves. This class of constraints specifically restricts the ordering in which violations can occur between sets of input-output (IO) FAITHFULNESS constraints. McCarthy proposes that the FAITHFULNESS constraints of the greatest interest for forming PRECEDENCE

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[26] Harmonic improvement also is bounded by the Characterization Theorem (Moreton 2003, McCarthy 2007; Tihonova 2009), which was originally devised for standard OT grammars. This theorem states that any OT grammar is eventually idempotent, in a sense that for any input there comes a point where the application of grammar to its own output will produce no further changes.

constraints are also the ones most relevant to *gradualness* for candidate chain formation. He defines these *basic* FAITHFULNESS[27] constraints as the non-positional ones of MAX, DEP, and the IDENT and LINEARITY families, which cover the full range of unfaithful mappings but do not overlap with one another (McCarthy 2007:79). These result in a more fundamental set of FAITHFULNESS violation orderings and thus, according to McCarthy, a narrow range of logically possible PRECEDENCE. PRECEDENCE constraints have the form and definition given in (25).

(25) PREC(A, B): (McCarthy 2007) assign a violation mark whenever

(a) an operation which violates basic FAITHFULNESS constraint B occurs, and is not preceded by an operation which violates basic FAITHFULNESS constraint A

(b) an operation which violates basic FAITHFULNESS constraint B occurs, and is followed by an operation which violates basic FAITHFULNESS constraint A

We can see in (25) that the (a)-clause essentially enforces sequential application. Conversely, the (b)-clause restricts a sequential application. As a result the effect of the two clauses together is somewhat analogous to earlier extrinsic rule ordering. Essentially, between the two logically possible ordering, we have the possible language preferences for the interaction of two phonological processes. While

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[27] *Basic faithfulness constraints*, following McCarthy and Prince (1995, 1999) are constraints that prohibit the deletion and insertion of elements of type x, constraints that prohibit changing particular features of such elements, and constraints that prohibit changing the linear order of elements. These constraints are also non-positional in terms of a particular structural position, i.e., onset, coda, etc.

McCarthy (2007) notes that the clauses for the PRECEDENCE constraints could in principle be split into individual constraints, he also claims that no language seems to actually require this. PRECEDENCE constraints have no role during stages of Harmonic Serialism since they do not evaluate the sequences in output candidates during construction. Only after GEN completes construction on all candidate chains do PRECEDENCE constraints become active in the grammar in order to compare the final state of the set of derivations. As such, they are a type of output-output (OO) FAITHFULNESS (Benua 1995, 1997; Burzio 1994) where they compare specific output sequences without reference to the input form.

Another important aspect of PRECEDENCE constraints is the required metaconstraint ranking for PRECEDENCE and FAITHFULNESS constraints: B » PREC(A, B) (Prince and Smolensky 1993/2004; McCarthy 2007). This metaconstraint serves to rule out certain unattested forms of opacity and ensures that satisfaction of the PRECEDENCE constraint cannot affect satisfaction of the B-FAITHFULNESS constraint.[28] Otherwise, some attested natural language processes could be restricted based solely on sequential ordering rather than the types of FAITHFULNESS violations that can occur. Importantly, the new class of PRECEDENCE constraints simply specifies possible orderings of violation assignments for existing FAITHFULNESS constraints. These orderings are not language specific, merely ranked within a language specific ordering. Furthermore, they are inherently part of the initial constraint inventory

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[28] McCarthy notes that while Prec(A,B) *depends* on whether B is violated, that it must never *affect* whether B is violated and this is achieved with the metaconstraint (but see McCarthy (2007: 99) for analysis of a counterbleeding scenario in Bedouin Arabic which led to proposing a metaconstraint).

and need not be invoked under special circumstances or introduced in language specific ways.[29] The following subsections outline an OT-CC account (McCarthy 2007) of the Bedouin Arabic counterfeeding and Tiberian Hebrew counterbleeding opacity scenarios introduced in §1.3.

1.5.2. OT-CC counterfeeding and counterbleeding resolution

Based on the Bedouin Arabic ranking of *COMPLEX » DEP, **a*CV » ID[LOW] (from (21)), Harmonic Serialism generates the sets of candidate chains in (26) for the inputs /katab/ and /gabr/. The attested output form is indicated by ✓.

(26) Candidate chains for vowel raising and epenthesis:

a. chains for input /katab/		b. chains for input /gabr/	
<ka.tab>	do nothing	<gabr>	do nothing
<ka.tab, ki.tab> ✓	raising	<gabr, ga.bur> ✓	epenthesis
		<gabr, ga.bur, gi.bur>	epenthesis; raising

As shown in (27), even with candidate chains the output selection problem in (22) remains since this constraint ranking still selects the transparently formed (feeding) candidate [gi.bur] as optimal.

[29] Although McCarthy (2007) observes that even if they were assumed to be derived during the acquisition process, they would still be limited to a narrow range of possible logical combinations.

(27) Tableau selecting transparent candidate in opaque scenario

/ka.tab/	*COMPLEX	DEP	**a*CV	ID[LOW]
a <ka.tab>			*!	
b ☞<ka.tab, ki.tab>				*
/gabr/				
a <gabr>	*!			
b →<gabr, ga.bur>		*	*!	
c ☜<gabr, ga.bur, gi.bur>		*		*

Unlike single form output candidates, which are evaluated in comparison to the input form, the challenge with candidate chains is to find a way to evaluate the internal stages of a chain. McCarthy (2007) shows how this chain-internal evaluation can be accomplished with PRECEDENCE constraints, since they specify the order in which FAITHFULNESS violations can occur. Recall that the non-positional FAITHFULNESS constraints restricting epenthesis and changes in vowel height are DEP and ID[LOW], respectively. PRECEDENCE orderings for violations to DEP and ID[LOW], based on the definitions in (25), are given in (28).

(28) *PREC(ID[LOW], DEP)*: assign a violation mark whenever

(a) a violation of DEP occurs and is not preceded by a violation of ID[LOW], or

(b) a violation of DEP occurs and is followed by a violation of ID[LOW]

PREC(DEP, ID[LOW]): assign a violation mark whenever

(a) a violation of ID[LOW] occurs and is not preceded by a violation of DEP, or

(b) a violation of ID[LOW] occurs and is followed by a violation of DEP

These PRECEDENCE constraints for ID[LOW] and DEP also have the required metaconstraints (form of B » PREC(A, B)) of DEP » PREC(ID[LOW], DEP) and ID[LOW] » PREC(DEP, ID[LOW]). The grammar representation in (29) includes both PRECEDENCE constraints in (28) with rankings that obey the metaconstraints.

(29) Tableau with PRECEDENCE constraints selecting opaque output

/ka.tab/	*COMPLEX	DEP	PREC (ID[LOW], DEP)	**a*CV	ID [LOW]	PREC (DEP, ID[LOW])
a <ka.tab>				*!		
b ☞<ka.tab, ki.tab>					*	*a
/gabr/						
a <gabr>	*!					
b ☞<gabr, ga.bur>		*	*a	*		
c <gabr, ga.bur, gi.bur>		*	*a*b!		*	

Crucially, ranking PREC(ID[LOW], DEP) over **a*CV eliminates the feeding candidate in the opaque case by assigning an additional (b)-clause violation to <gabr, ga.bur, gi.bur>, which leads to selection of the output form [ga.bur] as optimal. At this point, a relative ranking between DEP and **a*CV can be established via transitivity since PREC(ID[LOW], DEP) must be ranked below DEP to satisfy the metaconstraint and above **a*CV to eliminate the transparent, but unattested feeding interaction. Since there is no DEP violation for <ka.tab, ki.tab>, PREC(ID[LOW], DEP) also does not assign a violation and remains inactive during candidate evaluation for the transparent scenario. Thus, OT-CC can successfully represent Bedouin Arabic counterfeeding.

Based on the Tiberian Hebrew constraint ranking in (18), i.e., CODA-COND, *COMPLEX » MAX-C, DEP-V, Harmonic Serialism generates the set of candidate chains in (30) from the input /deʃʔ/.

(30) Candidate chains for input /deʃʔ/:

<deʃʔ>	do nothing
<deʃʔ, deʃ>	ʔ-deletion
<deʃʔ, deʃeʔ>	epenthesis
<deʃʔ, deʃeʔ, deʃe> ✓	epenthesis; ʔ-deletion

However, even with candidate chains the constraint ranking in (31), remains problematic because it selects <deʃʔ, deʃ> as the optimal candidate, and no permutation of these rankings will select the output <deʃʔ, deʃeʔ, deʃe>.

(31) Tableau selecting incorrect (transparently formed) candidate

/deʃʔ/	CODA-COND	*COMPLEX	MAX-C	DEP-V
a <deʃʔ>	*!	*		
b ☜<deʃʔ, deʃ>			*	
c <deʃʔ, deʃeʔ>	*!			*
d →<deʃʔ, deʃeʔ, deʃe>			*	*!

We again need to use PRECEDENCE constraints to evaluate the internal stages of these candidate chains. The PRECEDENCE violation sequences for MAX-C and DEP-V are given in (32), and have the corresponding metaconstraints of DEP-V » PREC(MAX-C, DEP-V) and MAX-C » PREC(DEP-V, MAX-C).

(32) *PREC(MAX-C, DEP-V)*: assign a violation mark whenever

(a) a violation of DEP-V occurs and is not preceded by a violation of MAX-C, or

(b) a violation of DEP-V occurs and is followed by a violation of MAX-C

PREC(DEP-V, MAX-C): assign a violation mark whenever

(a) a violation of MAX-C occurs and is not preceded by a violation of DEP-V, or

(b) a violation of MAX-C occurs and is followed by a violation of DEP-V

The ranking in (33) includes the PRECEDENCE constraints in a domination that minimally obeys the metaconstraints. In order to successfully represent Tiberian Hebrew counterbleeding it is only necessary to rank PREC(DEP-V, MAX-C), with its (a)-clause violation for an occurrence of a MAX-C violation that is not preceded by a violation of DEP-V, over DEP-V. This eliminates the unattested candidate chain <deʃʔ, deʃ> and selects the correct output <deʃʔ, deʃeʔ, deʃe> as optimal.

(33) Tableau selecting correct (opaque) output

/deʃʔ/	CODA-COND	*COMPLEX	MAX-C	PREC (DEP-V, MAX-C)	DEP-V	PREC (MAX-C, DEP-V)
a <deʃʔ>	*!	*				
b <deʃʔ, deʃ>			*	*a!		
c <deʃʔ, deʃeʔ>	*!				*	*a
d ☞<deʃʔ, deʃeʔ, deʃe>			*		*	*a*b

The successful opaque constraint ranking in (33) also selects the correct output in scenarios where ʔ-deletion and epenthesis apply transparently, as shown in (34). Thus, while transparent scenarios do not rely on PRECEDENCE constraint violations for correct output selection, this selection is also unaffected by including them and the grammar as a whole can be represented with a single constraint ranking.

(34) Tableau selecting outputs for transparent scenarios

/qaraʔ/	CODA-COND	*COMPLEX	MAX-C	PREC (DEP-V, MAX-C)	DEP-V	PREC (MAX-C, DEP-V)
a <qaraʔ>	*!					
b ☞<qaraʔ, qara>			*	*a		
/melk/						
a <melk>		*!				
b <melk, mel>			*!	*a		
c ☞<melk, melex>					*	*a
d <melk, melex, mele>			*!		*	*a*b

1.6. Unattested patterns of opacity and OT-CC modifications

In addition to well-attested opacity patterns such as counterfeeding and counterbleeding, Wolf (2011) suggests that there are also theoretically possible, although largely unattested, patterns of opacity. Wolf claims that patterns such as *mutual counterfeeding* and *mutual counterbleeding* are not ruled out on empirical grounds; however, he shows how they are ruled out as possible forms of natural language opacity by the metaconstraint restriction for OT-CC. If such patterns do exist in natural language, the theory would need to be modified in order to account for them. Wolf (2011) suggests the OT-CC modifications of lifting the metaconstraint requirement and splitting the PRECEDENCE constraint clauses, which minimally allows patterns such as mutual counterfeeding and mutual counterbleeding.[30]

Wolf (2011) acknowledges that justification for these modifications is dependent on evidence of natural language opacity requiring such a representation, but he points out works by Ballard (1971) and Bliese (1975) which appear to advocate the existence of mutual counterbleeding interactions. He also discusses a Hindi-Urdu analysis by Narang and Becker (1971) which supports a mutual counterfeeding interaction. Wolf additionally demonstrates how lifting the OT-CC metaconstraint requirement can successfully account for the historically problematic non-derived environment blocking (NDEB: Kenstowicz and Kisseberth 1970; Kiparsky 1973; Wolf 2008), but concludes that definitive natural language support remains elusive.

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[30] While he does not specifically analyze additional theoretically possible patterns, he does mention application of his proposal to counterfeeding from the past and non-derived environment blocking.

However, I argue that precisely such language evidence can be found in temporary forms of opacity which appear during early child acquisition. In spite of its transient nature, this acquisition data qualifies as natural language and therefore reinforces questions regarding the restrictiveness of standard OT-CC. Transient child opacity is the focus of this dissertation and I return to further discussion of it in chapter 2. The following sections outline Wolf's motivation for proposing lifting the metaconstraint and splitting the (a) and (b)-clauses into separately rankable constraints.

1.6.1. Lifting the metaconstraint for mutual counterbleeding

A mutual counterbleeding scenario can occur when a language has two potentially interacting processes and application of either process to a given input will cause the resulting form to no longer meet the structural description for the other process to apply. Therefore, each process stands in a potential bleeding relation to the other. Wolf (2011) creates a hypothetical language scenario in order to provide a clear illustration of where mutual counterbleeding could occur by using the natural language processes of *glide vocalization*, where glides vocalize when not adjacent to a vowel (e.g., /atj/ → [a.ti]), and *h-deletion*, where *h* deletes when it occurs before a consonant, before a glide, or in coda position (e.g., /pah/→ [pa]).

If these phonological processes apply sequentially, there are two possible orders for an underlying form such as /ahj/, which meets the structural description for both. If vocalization happens first, as in (35)a, vocalization will bleed *h*-deletion since the form no longer meets the structural description for *h*-deletion. If *h*-

deletion happens first, as in (35)b, *h*-deletion will bleed vocalization since the form no longer meets the structural description for vocalization.

(35) Possible process orders for input /ahj/:

a. vocalization then *h*-deletion		b. *h*-deletion then vocalization	
vocalize glide	[a.hi]	*h-deletion*	[aj]
h-deletion	*n/a*	*vocalize glide*	*n/a*
(vocalization has bled deletion)		(deletion has bled vocalization)	

However, since the input /ahj/ meets the structural description for both *h*-deletion and vocalization, it is also possible for both processes to apply *simultaneously*.[31] The two processes now interact in a mutually counterbleeding fashion since the glide vocalizes before *h*-deletion takes away the environment for vocalization, and the *h* deletes before vocalization takes away the environment for deletion. Consequently, both processes will apply, resulting in the output form in (36).

(36) Simultaneous process application: /ahj/ → [a.i]

Wolf proposes the MARKEDNESS constraints in (37)(a-c) to motivate h-deletion and vocalization, along with their conflicting FAITHFULNESS constraints in (37)(d-e).

[31] With simultaneous application, only the processes which can act on the underlying form are eligible to apply and additional processes are restricted from applying at a later time.

(37) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. *COMPLEX: assign one violation mark for every complex syllable margin

b. *CODA/h: assign one violation mark for every *h* in coda position

c. *GLIDE: assign one violation mark for every glide

d. ID[VOC]: assign one violation mark for every pair of segments standing in input-output correspondence with different values for the feature [VOCALIC]

e. MAX[h]: assign one violation for every input *h* with no output correspondent

The relative ranking for these constraints can be established based on transparent application of *h*-deletion and vocalization in this hypothetical language. For the input form /pah/, the grammatical output is [pa]. [pa] satisfies the MARKENDESS constraint *CODA/h while violating the FAITHFULNESS constraint MAX[h]; therefore, *CODA/h must outrank MAX[h] (i.e., *CODA/h » MAX[h]). For the input form /atj/, the grammatical output is [ati], therefore the satisfied MARKENDESS constraint *GLIDE must outrank the violated FAITHFULNESS constraint ID[VOC] (i.e., GLIDE » ID[VOC]). Similarly, [ati] also satisfies the MARKENDESS constraint *COMPLEX, indicating that *COMPLEX also outranks ID[VOC].[32] The general MARKEDNESS » FAITHFULNESS format in (38) gives us a grammar which will transparently derive [pa] from underlying /pah/ and [ati] from underlying /atj/.

[32] Wolf shows that this hypothetical language never violates *COMPLEX and this constraint receives an undominated ranking.

(38) Tableau for inputs /pah/ and /atj/

/pah/	*COMPLEX	*CODA/h	*GLIDE	MAX[h]	ID[VOC]
a [pah]		*!			
b ☞[pa]				*	
/atj/					
a [atj]	*!		*		
b ☞[a.ti]					*

However, when the inputs /aj/, where neither process applies, or /ahj/, where both processes apply, are evaluated under this constraint ranking, the correct output is not the optimal one, as shown by incorrect candidate selection in (39).

(39) Tableau for inputs /aj/ and/ahj/

/aj/	*COMPLEX	*CODA/h	*GLIDE	MAX[h]	ID[VOC]
a →[aj]			*!		
b ☜[a.i]					*
/ahj/					
a →[a.i]				*!	*
b [ahj]	*!	*	*		
c ☜[a.hi]					*
d [aj]			*!	*	

Furthermore, no constraint permutation that maintains the previously established MARKEDNESS and FAITHFULNESS rankings will select these opaque forms as optimal. Therefore, similar to the Tiberian Hebrew counterbleeding scenario in §1.4.2, mutual counterbleeding opacity also fails under standard OT. While such a failure is not unexpected at this point, a more significant implication from this opacity pattern is that it also fails under a standard OT-CC framework. In order to look at mutual counterbleeding under OT-CC, we need to first generate the set of output candidate chains, given in (40), using Harmonic Serialism.

(40) Candidate chains for *h*-deletion and glide vocalization:

a. chains for input /pah/

<pah>	*do nothing*
<pah, pa> ✓	*delete h*

b. chains for input /atj/

<atj>	*do nothing*
<atj, a.ti> ✓	*vocalize glide*

c. chains for input /aj/

<aj> ✓	*do nothing*
<aj, a.i>	*vocalize glide*

d. chains for input /ahj/

<ahj>	*do nothing*
<ahj, aj>	*delete h*
<ahj, a.hi>	vocalize glide
<ahj, aj, a.i> ✓	*delete h; vocalize glide*

The internal stages of these chains can be evaluated with PRECEDENCE constraints and the violation orderings for the relevant FAITHFULNESS constraints, those of MAX[h] and IDENT[VOC], are given in (41). These constraints also have the corresponding metaconstraints of ID[VOC] » PREC(MAX[h], ID[VOC]) and MAX[h] » PREC(ID[VOC], MAX[h]).

(41) *Prec(Max[h], Id[voc])*: assign a violation mark whenever

(a) a violation of Id[voc] occurs and is not preceded by a violation of Max[h], or

(b) a violation of Id[voc] occurs and is followed by violation of Max[h]

Prec(Id[voc], Max[h]): assign a violation mark whenever

(a) a violation of Max[h] occurs and is not preceded by a violation of Id[voc], or

(b) a violation of Max[h] occurs and is followed by a violation of Id[voc]

Unlike the Tiberian Hebrew counterbleeding scenario, obeying the metaconstraints for this mutual counterbleeding scenario merely results in the Precedence constraints being too lowly ranked to affect opaque output selection. Standard OT-CC essentially has the same optimal selections as standard OT, as shown in (42).

(42) Candidate selection based on obeying metaconstraints[33]

/aj/	*Com-plex	*Coda /h	*Glide	Max [h]	Prec (Id[voc], Max[h])	Id [voc]	Prec (Max[h], Id[voc])
a →<aj>			*!				
b ☜<aj, a.i>						*	*a
/ahj/							
a <ahj>	*!	*	*				
b <ahj, aj>			*	*	*a		
c →<ahj, aj, a.i>				*!	*a*b	*	
d ☜<ahj, a.hi>						*	*a

[33] Precedence constraints are not necessary to evaluate the transparent outputs in (38), but including Precedence constraints will also not impact optimal output selection for these scenarios.

The next step is to determine whether any ranking of these constraints will select both the correct opaque output and the correct transparent output. An efficient way to test this is to apply *recursive constraint demotion* (RCD) for *elementary ranking conditions*[34] (ERCs) in a comparative tableau to determine if there are ranking inconsistencies. A comparative tableau takes two output forms (candidate chains here) and the ERCs determine if a specific constraint favors the winner (W) or loser (L) in each pair based on the number of violations that constraint assigns to each form. The constraints can then be recursively ranked with respect to each other based on how many times each favors the winning candidate versus a failed candidate. A constraint ranking is considered consistent if each row has a W dominating every L.

A viable constraint ranking for this mutual counterbleeding scenario is generated in the comparative tableau in (43). Both *COMPLEX and *CODA/h have only Ws and they receive undominated rankings. PREC(MAX[h], ID[VOC]) must be ranked below *COMPLEX in order to select <atj, a.ti> over <atj>. The Ls for these constraints are unproblematic since they are already dominated by a W. Similarly, PREC(MAX[h], ID[VOC]) must dominate *GLIDE to select <aj> over <aj, a.i>. And finally, since *GLIDE must dominate ID[VOC] to allow glide vocalization at all, the metaconstraint ID[VOC] » PREC(MAX[h], ID[VOC]) must be violated.

[34] An ERC is a proposition about constraint ranking expressed as a winner/loser pair and a set of constraints, with each constraint annotated as to whether it favors the winner (indicated by a W), favors the loser (indicated by an L) or is indifferent (McCarthy 2008).

(43) Comparative tableau indicating violated metaconstraints

W~L	*COMPLEX	*CODA/h	PREC (MAX[h], ID[VOC])	*GLIDE	MAX [h]	ID [VOC]	PREC (ID[VOC], MAX[h])
<pah, pa>~ <pah>	(0~0)	W (0~1)	(0~0)	(0~0)	L (1~0)	(0~0)	L (1~0)
<atj, a.ti>~ <atj>	W (0~1)	(0~0)	L (1~0)	W (0~1)	(0~0)	L (1~0)	(0~0)
<aj>~ <aj, a.i>	(0~0)	(0~0)	W (0~1)	L (1~0)	(0~0)	W (0~1)	(0~0)
<ahj, aj, a.i>~ <ahj, aj>	(0~0)	(0~0)	(0~0)	W (0~1)	(1~1)	L (1~0)	L (2~1)
<ahj, aj, a.i>~ <ahj, a.hi>	(0~0)	(0~0)	W (0~1)	(0~0)	L (1~0)	(1~1)	L (2~0)
<ahj, aj, a.i>~ <ahj>	W (0~1)	W (0~1)	(0~0)	W (0~1)	L (1~0)	L (1~0)	L (2~0)

At this point, all Ls are dominated by a W and this indicates success in finding a consistent constraint ranking for this mutual counterbleeding scenario. The crucially ranked constraints are indicated by shading in (43) and the relative ranking of the unshaded constraints does not impact optimal output selection. This success comes at a cost, however, since it requires a non-trivial modification to OT-CC by requiring a metaconstraint violation. Such a modification carries significant theoretical implications (see McCarthy 2007 for discussion on the types of *permitted* FAITHFULNESS violations this would restrict). However, Wolf (2008) argues that this requirement in particular is not completely unmotivated in natural languages, claiming that there is an attested scenario of *obligatory counterbleeding* in Chimwin:ni which also requires a lifted metaconstraint representation.

1.6.2. Split Precedence for mutual counterfeeding

A mutual counterfeeding scenario can occur when a language has two potentially interacting processes, and application of either to a given input results in a form that satisfies the structural description for the other process to apply. Thus, each process stands in a potential feeding relation to the other. Wolf (2011) creates a hypothetical language scenario to demonstrate where mutual counterfeeding could occur by using the natural language processes of *ə-syncope* (i.e., *ə), where schwas delete except when a cluster of more than two consonants would result, and *h-deletion* (i.e., *hC), where *h* deletes before a consonant/glide or word-finally.

Again, there are two possibilities for sequential process application. If ə-syncope happens first, as shown in (44), ə-syncope will feed *h*-deletion and *h*-deletion will counterfeed ə-syncope. If *h*-deletion happens first, as shown in (45), *h*-deletion will feed ə-syncope and ə-syncope will counterfeed *h*-deletion. Each ordering culminates in a different final output.

(44) ə-syncope then *h*-deletion:		/ehtəmu/	/ahəpi/
	ə-syncope	n/a	[ahpi]
	h-deletion	[etəmu]	[api]

(45) *h*-deletion then ə-syncope:		/ehtəmu/	/ahəpi/
	h-deletion	[etəmu]	n/a
	ə-syncope	[etmu]	[ahpi]

However, simultaneous application, where neither process can apply at a later point, only permits application of processes which initially meet the structural description; it counterfeeds any subsequent process application. If application is simultaneous, only one will apply, limiting the outputs to the single forms in (46).

(46) Simultaneous process application:

a. /ehtəmu/ → [etəmu]

(UR meets structural description of *h*-deletion but not *ə*-syncope)

b. /ahəpi/ → [ahpi]

(UR meets structural description of *ə*-syncope but not *h*-deletion)

Wolf proposes the MARKEDNESS constraints in (47)(a-b) to motivate ə-syncope and h-deletion as well as the constraint in (47)(c) to restrict sequences of more than two consonants. These have the conflicting FAITHFULNESS constraints in (47)(d-e).

(47) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. *hC: assign one violation for every sequence of *h* followed by a consonant

b. *ə: assign one violation mark for every *ə*

c. *CCC: assign one violation mark for every sequence of three consonants

d. MAX[h]: assign one violation for every input *h* with no output correspondent

e. MAX[ə]: assign one violation for every input *ə* with no output correspondent

The relative ranking for these constraints in this hypothetical language can be established in a manner similar to that of the mutual counterbleeding scenario. Transparent process application from Wolf (2011) results in the following constraint relationships: *CCC is never violated and is undominated. Deletion of *h* gives the ranking *hC » MAX[h]. Deletion of *ə* gives the ranking *ə » MAX[ə]. Wolf further proposes the constraint ranking *CCC » *ə » *hC » Max[h], where *ə is ranked between *CCC and *hC based on additional output forms (see Wolf (2011) for details). The possible output forms for this language can be evaluated under this ranking in the violation tableau in (48).

(48) Failed OT tableau for inputs /ehtəmu/ and /ahəpi/

/ehtəmu/	*CCC	*ə	*hC	MAX[h]	MAX[ə]
a →[etəmu]		*!		*	
b [ehtəmu]		*!	*		
c ☜[etmu]				*	*
d [ehtmu]	*!		*		
/ahəpi/					
a →[ahpi]			*!		*
b [ahəpi]		*!			
c ☜[api]				*	*

Similar to the Bedouin Arabic counterfeeding scenario in §1.4.2, we can see that this mutual counterfeeding scenario shows immediate ranking conflicts under standard OT in the violation tableau in (48). Furthermore, the ranking conflicts for mutual counterfeeding which appear under standard OT also persist under standard OT-CC. In order to look at mutual counterfeeding under OT-CC, we again first generate the set of output candidate chains, given in (49), using Harmonic Serialism.

(49) Candidate chains for *h*-deletion and *ə*-syncope:

a. <u>chains for input /ehtəmu/</u>		b. <u>chains for input /ahəpi/</u>	
<ehtəmu>	*do nothing*	<ahəpi>	*do nothing*
<ehtəmu, etəmu> ✓	*delete h*	<ahəpi, ahpi> ✓	*delete ə*
<ehtəmu, etəmu, etmu>	*del h; del ə*	<ahəpi, ahpi, api>	*del ə; del h*

These candidate chains also require PRECEDENCE constraints to evaluate their internal stages. The logically possible PRECEDENCE orderings for the FAITHFULNESS constraints MAX[h] and MAX[ə] are given in (50). These constraints have the corresponding metaconstraints of MAX[ə] » PREC(MAX[h], MAX[ə]) and MAX[h] » PREC(MAX[ə], MAX[h]).

(50) <u>*PREC(MAX[h], MAX[ə])*: assign a violation mark whenever</u>

(a) a violation of MAX[ə] occurs and is not preceded by a violation of MAX[h], or

(b) a violation of MAX[ə] occurs and is followed by a violation of MAX[h]

<u>*PREC(MAX[ə], MAX[h])*: assign a violation mark whenever</u>

(a) a violation of MAX[h] occurs and is not preceded by a violation of MAX[ə], or

(b) a violation of MAX[h] occurs and is followed by a violation of MAX[ə]

However, inclusion of the PRECEDENCE constraints for a standard OT-CC analysis predictably has no impact on optimal output selection, as shown in (51).

(51) Failed standard OT-CC tableau for inputs /ehtəmu/ and /ahəpi/

/ehtəmu/	*CCC	*ə	*hC	MAX [h]	PREC (MAX[ə], MAX[h])	MAX [ə]	PREC (MAX[h], MAX[ə])
b <ehtəmu>		*!	*				
a →<ehtəmu, etəmu>		*!		*	*a		
c ☜<ehtəmu, etəmu, etmu>				*	*a*b	*	
d <ehtəmu, ehtmu>[35]	*!		*			*	*a
/ahəpi/							
b <ahəpi>		*!					
a →<ahəpi, ahpi>			*!			*	*a
c ☜<ahəpi, ahpi, api>				*		*	*a*b

The crucial question at this point is whether any ranking, regardless of obeying the metaconstraint or not, will select the correct outputs. To test for a possible consistent ranking, we can again apply recursive constraint demotion for elementary ranking conditions in a comparative tableau, as in (52). The first RCD pass successfully ranks *CCC since it only has a W, but RCD crashes on the next pass because all of the remaining constraints assign at least one L that will be undominated by a W. This indicates a fatal ranking inconsistency that cannot be resolved with any permutation of these constraints.

[35] While not a harmonious change, this candidate is included to show activity of *CCC.

(52) Comparative tableau highlighting ranking inconsistencies

W~L	*CCC	*ə	*hC	Max [h]	Max [ə]	Prec (Max[ə], Max[h])	Prec (Max[h], Max[ə])
<ahəpi, ahpi>~ <ahəpi, ahpi, api>	(0~0)	(0~0)	L (1~0)	(1~1)	W (0~1)	(0~0)	W (0~1)
<ahəpi, ahpi>~ <ahəpi>	(0~0)	W (0~1)	L (1~0)	L (1~0)	(0~0)	(0~0)	L (1~0)
<ehtəmu, etəmu>~ <ehtəmu, etəmu, etmu>	(0~0)	L (1~0)	(0~0)	W (0~1)	(1~1)	W (0~1)	(0~0)
<ehtəmu, etəmu>~ <ehtəmu>	(0~0)	(1~1)	W (0~1)	(0~0)	L (1~0)	L (1~0)	(0~0)
ehtəmu>ehtmu	W (0~1)	L (1~0)	(1~1)	W (0~1)	(0~0)	(0~0)	(0~0)

However, Wolf (2011) demonstrates how this ranking inconsistency can be resolved by splitting the Precedence constraints into separate (a) and (b)-clauses and forming individually rankable constraints from these clauses. He proposes the general form in (53) for split Precedence constraints.

(53) Prec(A, B) splits into A←B and *B-then-A:

(a) A←B: B violation must be preceded by A violation

(b) *B-then-A: no A violation after B violation

Each of these individual constraints looks at only a single directional ordering for pairs of Faithfulness constraint violation. Following Wolf, the constraints Prec(Max[h], Max[ə]) and Prec(Max[ə], Max[h]) can be split as in (54) and (55).

(54) PREC(MAX[h], MAX[ə]) splits into:

(a) MAX[h]←MAX[ə]: MAX[ə] violation must be preceded by MAX[h] violation

(b) *MAX[ə]-THEN-MAX[h]: no MAX[h] violation after MAX[ə] violation

(55) PREC(MAX[ə], MAX[h]) splits into:

(a) MAX[ə]←MAX[h]: MAX[h] violation must be preceded by MAX[ə] violation

(b) *MAX[h]-THEN-MAX[ə]: no MAX[ə] violation after MAX[h] violation

These split constraint forms now replace the original conjoined PRECEDENCE constraints in the constraint inventory and recursive constraint demotion can again be applied in a comparative tableau to determine if there are any ranking inconsistencies. As shown in (56), the undominated constraints, i.e., those with only Ws, now include *CCC and the former (b)-clause constraints *MAX[ə]-THEN-MAX[h] and *MAX[h]-THEN-MAX[ə]. The remaining crucial Ws are supplied by *ə and *hC. However, *ə must be dominated by both *CCC and *MAX[h]-THEN-MAX[ə] and *hC must be dominated by *ə. At this point, recursive constraint demotion in a comparative tableau has determined a successful constraint ranking since every row with an L has a W ranked to the left. The remaining constraints, i.e., the FAITHFULNESS constraints MAX[h] and MAX[ə], and the (a)-clause constraints MAX[h]←MAX[ə] and MAX[ə]←MAX[h], can remain unranked relative to each other.

Furthermore, since Max[h]←Max[ə] and Max[ə]←Max[h] only prefer losing candidates they can be omitted from this tableau for the sake of space.

(56) Comparative tableau with (b)-clause split Precedence constraints[36]

W~L	*CCC	*Max[h] -then- Max[ə]	*Max[ə] -then- Max[h]	*ə	*hC	Max [h]	Max [ə]
<ahəpi, ahpi>~ <ahəpi, ahpi, api>	(0~0)	(0~0)	W (0~1)	(0~0)	L (1~0)	(1~1)	W (0~1)
<ahəpi, ahpi>~ <ahəpi>	(0~0)	(0~0)	(0~0)	W (0~1)	L (1~0)	L (1~0)	(0~0)
<ehtəmu, etəmu>~ <ehtəmu, etəmu, etmu>	(0~0)	W (0~1)	(0~0)	L (1~0)	(0~0)	W (0~1)	(1~1)
<ehtəmu, etəmu>~ <ehtəmu>	(0~0)	(0~0)	(0~0)	(1~1)	W (0~1)	(0~0)	L (1~0)
ehtəmu>ehtmu	W (0~1)	(0~0)	(0~0)	L (1~0)	(1~1)	W (0~1)	(0~0)

We have seen in this section how Wolf's proposed modifications of lifting the metaconstraint and splitting the Precedence constraint clauses into individually rankable constraints allows OT-CC to represent mutual counterbleeding and mutual counterfeeding. Thus far, these hypothetical language examples only serve to illustrate modified OT-CC representations of possible opacity patterns. However, the full utility of such modifications is explored in chapter 2, where I show that they are precisely the modifications required to represent the opaque outputs which temporarily appear during early child acquisition.

[36] This constraint ranking is equally successful in the earlier violation tableau format.

1.7. Conclusion

This chapter began by showing that derivational approaches are able to provide a fairly straightforward account of transparent and opaque phonological interactions through process application ordering. By contrast, a constraint ranking approach like OT, while superior in terms of capturing typological generalizations fails to account for many types of opacity. However, as illustrated in §1.5, the problem of representing opacity is greatly mitigated by certain theoretical extensions, in particular OT-CC. Furthermore, OT-CC provides additional theoretical advantages over a derivational approach, since the order in which processes must apply reveals nothing of a general blocking or triggering effect, leaving no way to distinguish between under- and over-application opacity. In comparison, under- and over-application opacity are inherently distinguished under OT-CC through different (a) and (b)-clause PRECEDENCE violation assignments. Thus, the theoretical implications of OT-CC extend beyond simply representing opaque interactions.

The specific formulations of OT-CC also give it the ability to make predictions regarding certain types of process interactions occurring, or being restricted from occurring, in natural language. In particular, McCarthy discusses how imposing the metaconstraint ranking—of the B-FAITHFULNESS constraint ranked over the PRECEDENCE constraint—is intended to restrict unattested forms of opaque interactions. This metaconstraint also rules out possible violation assignments that may themselves restrict attested language processes. The predictive power of OT-CC is an additional advantage such a constraint ranking system has over a derivational system, which makes no predictions regarding possible opaque interactions.[37] However, standard OT-CC predicts that simultaneous application patterns, such as (marginally attested) mutual counterfeeding and mutual counterbleeding, will not occur in natural language. These predictions are challenged by Wolf (2011), who argues that this may be overly restrictive based on such theoretically possible opacity patterns, thus making certain modifications to OT-CC desirable.

Therefore, if natural language opacity patterns do extend beyond the sequential patterns typically found in mature grammars, Wolf's proposed modifications would expand the theory and allow these patterns to be accounted for under OT-CC.[38] Throughout the remainder of this dissertation, I argue that the opaque productions which temporarily appear during stages of early child acquisition are precisely this type of opacity. OT-CC's ability to distinguish between enforcing and restricting sequential process application, combined with Wolf's (2011) modifications which allow these restrictions to function separately and remain unbound by the metaconstraint, make a modified OT-CC representation ideal for early child opacity.

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[37] The formulations of OT-CC were intended as a way to limit types of over-generation, but in spite of this, it has received criticism over its potential over-generation of opaque forms. In particular, Wilson (2006) shows that OT with Candidate Chains can produce an unattested type of opaque interaction he calls *counterfeeding from the past*. (Although see Wolf (2010) for claims that scenarios of counterfeeding from the past appear under certain *rule-ordering* paradoxes.) In contrast, while a rule-based system predicts opacity (Kiparsky 1968, 1971), it fails to make predictions regarding the types of patterns that should or should not be possible in natural language.

[38] However, the simultaneous process application of mutual counterfeeding and mutual counterbleeding remains severely problematic for derivational accounts since it is not predicted to occur under extrinsic orderings (but see Ringen (1972) for discussion of intrinsic rule orders).

I turn to the details of such an analysis next in chapter 2, where I illustrate how application of OT-CC can reveal previously unpredicted patterns of opacity, and modifications to OT-CC can at least partially explain underlying differences.

CHAPTER 2:
UNPREDICTED OPACITY IN EARLY CHILD ACQUISITION

2.1. Introduction

We saw in chapter 1 that standard OT-CC successfully represented the attested mature language opacity patterns of counterbleeding and counterfeeding. Furthermore, specific formulations of OT-CC, such as the metaconstraint and the conjoined PRECEDENCE clauses, were intended to limit types of over-generation. Consequently, OT-CC predicts that patterns which do not conform to these formulations will not occur in natural language. However, we also saw that it is possible that such predictions may be too restrictive. Wolf (2011) suggests that patterns of opacity specifically restricted by OT-CC are not necessarily ruled out empirically and that natural language may provide evidence of their existence.

In this chapter I examine several scenarios of child under-application opacity that temporarily appear during early L1-acquisition stages and show how not just standard OT but even standard OT-CC fails to represent them. This outcome is unexpected since it is contra to predictions that opaque productions during child acquisition can be accounted for under either standard OT or standard OT-CC (Jesney 2005, 2007; Vanderweide 2006; Dinnsen *et al*. 2011, among others). Here, I show that although these cases do not at first glance appear to be significantly different from adult counterfeeding opacity, attempting a standard OT-CC analysis reveals a pattern the current theory predicts will not occur in natural language.

Failure of standard OT-CC with this temporary opacity pattern also implies that OT-CC, as originally formulated, may be too restrictive in terms of the types of opacity it predicts to be possible in natural language. However, I propose that the two key modifications to OT-CC suggested by Wolf (2011) allow it to account for both this unpredicted child pattern and the well-established counterfeeding and counterbleeding patterns. It is not entirely surprising that standard OT-CC neither predicts nor accounts for this pattern of opacity—it appears to be restricted to early stages of acquisition, and early child productions are not the type of data targeted by McCarthy. Moreover, the patterns of opacity which temporarily appear in early child acquisition are similar to the hypothetical patterns of mutual counterbleeding and mutual counterfeeding in unexpected ways. However, I show that the ways in which these forms of opacity can be represented via specific modifications to OT-CC make it a particularly useful diagnostic for revealing and classifying patterns of opacity which have not been identified under other theoretical extensions.

The remainder of this chapter is organized in the following manner. In §2.2 I review several conflicting proposals for explaining opaque forms in early child production, ranging from lexical inertia and temporary word fossilization to fixed constraint rankings in standard OT. In §2.3 I examine data from English child diary studies where the children go through a stage in which they produce under-application chain shifts not attested in the adult grammar. Amahl (~2;2) exhibits non-target processes of stopping (e.g., *z>d*) and velarization of coronals (e.g., *d>g*) before laterals (Smith 1973). Joan (~1;10) exhibits non-target processes of denasalization (e.g., *n>d*) and coda devoicing (e.g., *d>t*) word finally (Velten 1943). In §2.4 I examine over-application data from an English child diary study where child 1 applies vowel lengthening in non-target ways in conjunction with devoicing final codas (Barlow and Keare 2008). Each child opacity scenario is shown to fail under standard OT and standard OT-CC and re-analyzed under the modified version of OT-CC proposed by Wolf (2011). Finally, in §2.5 I discuss general acquisition reasons for contrasts between initial-state (or early acquisition) opacity and final-state opacity and preliminary ways these differences are formalized in OT-CC.

2.2. Alternative approaches to child opacity

While opaque outputs during stages of child acquisition are well documented, the attempts at describing these phenomena within an OT framework are far from consistent and draw from a range of theoretical approaches and expansions to standard OT (Dinnsen *et al*. 2000; Fikkert 2006; Vanderweide 2006; Jesney 2007; Tihonova 2009; Dinnsen *et al*. 2011; among others). Child opacity approaches range broadly between appealing to production-driven and theoretical explanations. However, these alternative approaches find common ground in that they eschew introducing additional formal mechanisms to account for child acquisition productions. In this section I review a select few alternative approaches for representing opaque forms in child production.

2.2.1. Production-driven accounts

Some cases of non-stable grammar opacity, particularly what look like opaque productions in child acquisition, have been argued to reflect other factors related to the developing grammar. Production-driven accounts include claims that apparent child opacity is actually the result of external factors such as lexical inertia and temporary word fossilization rather than true opaque process interactions in the grammar. Ettlinger (2009) looks at data from a multi-stage diary study of child M and argues that what appears to be opacity in her grammar is the result of word age (i.e., how long ago the word entered her vocabulary) and residual, but temporary, fossilization of output forms resulting from previously active phonological processes (see also Tessier 2009 for additional claims of fossilized forms appearing in stages of child acquisition). In keeping with other production-driven accounts, Ettlinger claims that an apparent chain shift in this child's acquisition is actually an effect of *lexical inertia* (Menn and Stoel-Gammon 1993), where words which entered the lexicon at an earlier time are more resistant than new words to currently active processes. For example, he shows that child M at Stage 1(1;0-1;4) produces [kʌk] for *talk*. Here, velarization applies and /t/ → [k]. At Stage 2 (1;4-1;7), child M continues to produce [kʌk] for *talk*, but now also produces [tɑk] for *sock*, showing that stopping applies with /s/ → [t]. If velarization was active at the time [kʌk] entered child M's lexicon, but it is no longer active at the time [tɑk] enters, this would explain why [tɑk] ↛ [kɑk]. However, the appearance of velarization continues in [kʌk], which has temporarily *fossilized* in this form.

Ettlinger suggests that this provides evidence for stages of *lexical optimization* in OT, where the underlying form of a lexical item corresponds to the optimal surface form. However, a lexical inertia/optimization analysis is highly dependent on the assumption that the potentially interacting phonological processes are not active at the same time. Concurrent activity is, of course, an underlying assumption for processes interacting opaquely in stable grammars and an essential component of true opacity. It follows then that a lexical inertia/optimization argument against child opacity would be greatly undermined if the two processes in question act upon the same word as it enters the lexicon. I show that this is precisely the case for child M in chapter 4, where evidence of activity for both velarization and stopping in the same word (/ti.vi/ → [ki.bi]) supports concurrent activity of these processes.[39]

2.2.2. Strictly parallel OT accounts

Other approaches to accounting for opaque forms in child production claim they are indeed the result of opaque (and therefore concurrent) process interactions, but strive to limit representation to a standard (i.e., parallel) OT framework (Dinnsen and Barlow 1998; Dinnsen and McGarrity 2004; Jesney 2007; Dinnsen, O'Connor and Gierut 2001). Such theoretical approaches rely on specific constraint

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[39] Since evidence of concurrent activity supports a claim of opaque process interactions, I also re-analyze the stages of M's acquisition under a modified OT-CC analysis in chapter 4.

hierarchies and other inherently fixed rankings, but avoid using additional formal mechanisms or invoking particular theoretical expansions to standard OT.

The following counterfeeding opacity data come from the well-known diary study of the child Amahl (Smith1973; see also Macken 1980). Amahl's production data contains two potentially interacting phonological processes: fricatives become stops (stopping) and coronal segments become velar segments (velarization).[40] Application of these phonological processes can be seen in the tokens in (1).

(1) *puzzle-puddle-pickle* chain shift of Amahl - age 2;2-2;11

a. stopping: fricatives > stops (all contexts)

[pʌdl̩]	'puzzle'	[b̥ɛtl̩]	'pencil'
[pɛtl̩]	'special'	[pa:tli:]	'parsley'

b. velarization: coronals > velars (before laterals)

[pʌgl̩]	'puddle'	[tʰə:kl̩]	'turtle'
[tæŋgl̩]	'sandal'	[dzə:ŋl̩]	'journal'

c. no continuance or place change: /k/ realized as [k]/[g]

[pɪkl̩]	'pickle'	[b̥ʌgl̩]	'buckle'
[ʌŋkl̩]	'uncle'	[tɔklɪt]	'chocolate'

[40] This velarization of coronals appears to be idiosyncratic and not directly motivated by the target language. A non-adult preference for velar segments in early child data may result from children having a different set of articulatory and perceptual constraints (Inkelas and Rose 2007).

When a segment meets the structural requirements for both velarization and stopping, these processes have potential to interact in a feeding sequence. However, outputs produced by such sequences, such as *z>d>g,* are not attested in Amahl's grammar. We have seen in chapter 1 that in general, a parallel analysis prefers feeding interactions and requires additional mechanisms, such as the formulations of OT-CC, to eliminate counterfeeding candidates as optimal.

However, Jesney (2005) argues against opacity-specific expansions to standard OT by suggesting that developmental chain shift patterns result from interaction of key markedness conditions with harmonic scales expressed in terms of hierarchically ranked IDENTITY constraints. She suggests that chain shifts arise in developing grammars when input forms are target-like in their specification and demotion of MARKEDNESS constraints has begun, but has not progressed to the final adult-like ranking. This creates a scenario where a MARKEDNESS constraint that should trigger the second stage of the chain shift is ranked between two harmonically-ranked FAITHFULNESS constraints and the effects of this MARKEDNESS constraint can only be realized in a subset of input forms.

For example, in the case of Amahl, Jesney (2005) claims that harmonically ranked IDENTCORONAL constraints interact with the MARKEDNESS constraints *[+STR] and *TL in a ranking such as *[+STR], IDCOR/[+STR] » *TL » IDCOR/[-STR]. This grammar prefers non-strident coronals, i.e., coronal stops, rather than velars for repairing strident coronal segments, as shown in (2).

(2) Harmonically ranked IDENTCORONAL constraints

/pʌdl̩/	*[+STR]	IDCOR/[+STR]	*TL	IDCOR/[-STR]
a [pʌdl̩]			*!	
b ☞[pʌgl̩]				*
/pʌzl̩/				
a [pʌzl̩]	*!			
b ☞[pʌdl̩]			*	
c [pʌɣl̩]		*!		
d [pʌgl̩]		*!		

IDCOR/[+STR] is only violated when the coronality of the input is altered, so as we can see in the tableau in (2), this ranking selects [pʌdl̩] as more optimal than [pʌgl̩] for input /pʌzl̩/ in spite of [pʌdl̩] violating lower ranked *TL since the coronality of [d] satisfies IDCOR/[+STR]. These harmonically ranked IDENTCORONAL constraints thus appear to provide the crucial IDENTITY violation over the constraint which motivates velarization (*TL). However, additional production data shows that constraints which distinguish between [±STRIDENT] as a feature of CORONAL identity may be too specific overall in this early grammar. Amahl also reduces /s/+stop cluster, as shown in (3).

(3) */st/ and /sk/ cluster treatment in Amahl's grammar*

a. cluster occurs word-medially

[pɪ**t**l̩] 'pistol' [ra:**k**l̩] 'rascal'

[p^{h}o:**t**l̩] 'postal'

b. cluster occurs word-initially

[**ḍ**eɪn]	‘stain’	[**g**ɪn]	‘skin’
[**tʰ**ɛdiː]	‘steady’	[**kʰ**aɪ]	‘sky’
[**t**aːrd]	‘stars’	[**k**eɪld]	‘scales’
[**t**əund]	‘stones’	[**k**ɪpɪn]	‘skipping’

One possibility, suggested by Smith (1973), is that Amahl treats word-medial pre-lateral /st/ cluster as [s] rather than [t]. The resulting [sḷ] would then undergo stopping to be produced as [tḷ]. In this case, derived environment velarization (e.g., /pɪsḷ/ → [pɪtḷ] ↛ [pɪkḷ]) would need to be blocked, similar to /pʌzḷ/ → [pʌdḷ] ↛ [pʌgḷ]. However, we can see in (3) that word medial /sk/ clusters reduce to [k] and both word-initial /s/+stop clusters reduce to the stop. Furthermore, assuming a consistent pattern of /s/+stop becoming a stop, as opposed to a sequence of reduction of /st/ to [s] and then applying stopping to get [t], seems a more reasonable stance for this data. Jesney also assumes /st/ reduces to [s] since reduction to [t] would be problematic for her approach of harmonically ranked IDENTCORONAL constraints. Without an *s>t>k* sequence, outputs with [kḷ] cannot be eliminated by IDCOR/[+STR] violations, as shown in (4).[41] This tableau includes MAX to account for the segment deletion violations, but it receives a low ranking since it is not a grammatical solution to [+STRIDENT] segments in other contexts.

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[41] See §2.3.1 for an alternative analysis of this scenario and Amahl’s other productions.

(4) Opaque failure under harmonically ranked IDENTCORONAL constraints

/p^ho:stl̩/	*[+STR]	IDCOR/[+STR]	*TL	IDCOR/[-STR]	MAX
a [p^ho:stl̩]	*!				
b →[p^ho:tl̩]			*!		*
c ☜[p^ho:kl̩]					*
/pɪstl̩/					
a [pɪstl̩]	*!				
b →[pɪtl̩]			*!		*
c ☜[pɪkl̩]					*

Furthermore, Jesney claims that a harmonically ranked IDENTITY analysis is dependent on the grammar containing an earlier constraint ranking stage where a full neutralization, i.e., a feeding chain-shift pattern, is preferred. However, specific documentation of such a stage preceding the emergence of counterfeeding is generally rare in child acquisition literature and thus difficult to reliably assume.

Vanderweide (2006) similarly argues that opacity during stages of acquisition can be represented using universally fixed hierarchies of perceptually motivated constraints implemented in *harmony-as-faithfulness*. Her focus is on learning within possible constraint hierarchies and she claims that within each hierarchy, learners begin with all MARKEDNESS constraints ranked above all FAITHFULNESS constraints and demote MARKEDNESS constraints below FAITHFULNESS constraints. However, rather than remaining within a universally fixed hierarchy, her account ultimately relies on using Local Constraint Conjunction for IDENT (MANNER and PLACE) violations to rule out Amahl's opaque potential chain shifts in early stages of acquisition. Constraint conjunction, while not necessarily in conflict with a parallel constraint raking account, does require a theoretical divergence with fixed harmonic rankings and use of constraints derived outside of CON. Hence, such constraints cannot be considered to participate in universally fixed hierarchies. However, I return to a more explicit account of Amahl's opacity under Local Constraint Conjunction in chapter 5.

The diversity of accounts for opacity during child acquisition indicates that the source and nature of opaque forms in child production is far from settled. In this dissertation I follow proposals which claim that opaque forms in both child and adult grammars are the result of opaque phonological process interactions (Dinnsen *et al*. 2000; Fikkert 2006; Vanderweide 2006; Jesney 2005, 2007; Tihonova 2009; Dinnsen *et al*. 2011; among others). Evidence from diary studies (Velten 1943; Smith 1973; Cho and Lee 2003) supports claims of true opaque interactions by showing overlap of activity for processes with potential to interact in feeding chains shifts, but which opaquely fail to do so. However, I suggest that there are theoretical distinctions between the types of opaque productions found in early child and adult grammars and that differences between these patterns can only be accounted for under specific extensions to standard OT. I further argue that rather than child opacity being *triggered* (Jesney 2005) through particular rankings in select grammars, early child opacity reflects a normal stage of acquisition that follows directly from the structure in the initial state. Importantly, while some parallel OT approaches reference the initial state, none of them reveal the fundamental pattern distinction between child and adult opacity that is ultimately highlighted by OT-CC.

2.3. The nature of transient under-application opacity

Under-application opacity, particularly what appears to be counterfeeding chain shifts, is the most prevalent type to appear during stages of child acquisition.[42] Counterfeeding chain shifts involve the interaction of two phonological processes where A→B and B→C, but it is never the case that A→C, as illustrated by Amahl's productions in (1). This results in a non-surface true generalization since the potential feeding relationship (A→B→C) is blocked. Dinnsen *et al*. (2011) observe that this lack of feeding is particularly unexpected in L1-acquisition since feeding interactions are considered the most unmarked form of process interaction (see also Kiparsky 1971). Feeding interactions result in surface true generalizations, and as such, they naturally fall out of MARKEDNESS over FAITHFULNESS rankings under standard OT. Furthermore, they are expected to transparently emerge from the initial state (as proposed by Smolensky 1996), since the optimal output is one which satisfies MARKEDNESS constraints in spite of violations to FAITHFULNESS constraints.

Furthermore, while counterfeeding chain shifts also frequently appear in adult opacity (see Moreton 2010 for a good overview), the chain shifts appearing in child

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[42] Wolf (2008: 256) also observes that the approach in Jesney (2005), combined with McCarthy's suggested initial state ranking of PRECEDENCE, would predict that chain shifts would be the only expected form of *spontaneous* opacity. This initially appears to correspond with a typological preference for counterfeeding opacity; however, the frequent appearance of chain shifts during stages of both child and adult language acquisition is explored further in chapter 3.

grammars are different from those in adult grammars in several ways. One obvious way is that the processes in the child grammars are frequently non-target in the sense that they do not appear to be directly motivated by the target grammar, e.g., velarization of coronals (*d>g*) or denasalization (*d>n*) in English. Non-target patterns developing during in first language acquisition are well-documented in the acquisition literature (Velten 1943; Braine 1976; Goad 1997; Macken 1980; Pater 1997; Smith 1973; Stemberger and Stoel-Gammon 1991; Cho and Lee 2003; among others). Phonological processes that are either not evident in the target grammar, or are applied in a manner that is inconsistent with the target grammar, frequently appear and then disappear during early acquisition stages.

Additionally, these phonological processes appear to be less inherently restricted by early constraint rankings and this leads to a broader-scope application (i.e., less context specific) in child grammar.[43] This is consistent with acquisition literature claiming that children tend to over-generalize more than adults (Hudson Kam and Newport 2005; among others). Such broad-scope application of linguistic generalizations is not specific to phonological production, but appears across a wide range of early child utterances, such as morphological paradigm over-regularization, e.g., using *goed* instead of *went* and *foots* instead of *feet*. Broader application of phonological generalizations results in an over-generation of viable, but unattested,

[43] Culbertson points out that such application would be distinct in any case if the phonological processes the children are applying are not found in the target grammar. However, the contrast between context specific adult application and broad child application also occurs during acquisition of an artificial language with non-L1 processes for both (Hudson Kam and Newport 2005).

candidate chains. I illustrate such phonological over-generation problems in child chain shifts, along with how they can be resolved under a modified version of OT-CC, in the following subsections as well as in chapters 3 and 4. It is worth noting that well-documented instances of early child acquisition opacity are relatively rare. However, here I discuss the all clearly identified cases which resulted from a comprehensive search of the literature.

2.3.1. Child chain shift from Smith (1973)

We saw in (1) that Amahl's grammar (Smith 1973) contains the two potentially interacting phonological processes of stopping and velarization of coronals and these processes opaquely fail to interact in a sequential feeding chain shift such as /pʌzl̩/ → [pʌdl̩] → [pʌgl̩]. I follow Maken (1980, Dinnsen and Barlow (1998), Jesney (2005), Vanderweide (2006) and Dinnsen *et al*. (2011), among others, in treating these outputs as the result of categorical and productive opaque process interactions. In general, this appears to imply some type of forced sequencing or blocking of sequential application of these processes. However, if the processes of stopping and velarization apply sequentially to an input form, both ordered interactions result in an unattested output form, as shown in (5) and (6).

(5) Velarization happens first:	/pʌzl̩/ 'puzzle'	/pʌdl̩/ 'puddle'
velarization	[pʌɣl̩]	[pʌgl̩]
stopping	[pʌgl̩]	*n/a*

(6) Stopping happens first: /pʌzl̩/ 'puzzle' /pʌdl̩/ 'puddle'

stopping	[pʌdl̩]	*n/a*
velarization	[pʌgl̩]	[pʌgl̩]

Furthermore, the results from these two ordered applications provide an early indication that this opacity cannot be true counterfeeding since either process ordering results in a feeding interaction. Following Baković (2011), true counterfeeding is a *counterfactual inverse* of feeding in the sense that if one ordering of the two processes involved results in a counterfeeding interaction, then an opposite ordering would result in feeding interaction. However, if stopping and velarization apply simultaneously to an input form, similar to Wolf's mutual counterfeeding illustration where neither process can apply to a modified form at a later stage, the outputs are limited to those in (7) but include both attested forms.

(7) Simultaneous process application:

a. /pʌzl̩/ → [pʌdl̩] (UR meets structural description of stopping)

↘ [pʌɣl̩] (UR meets structural description of velarization[44])

b. /pʌdl̩/ → [pʌgl̩] (UR meets structural description of just velarization)

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44 Although [pʌɣl̩] is unattested as an output, it is a legitimate element of a chain shift and failed candidate since it is formed through harmonious application of velarization.

Unlike Wolf's mutual counterfeeding illustration, the underlying representation for Amahl in (7)a meets the structural description for more than one process. Consequently, simultaneous application will still over-generate non-optimal forms. However, this does not appear to be problematic as long as they can be eliminated via high rankings of specific MARKEDNESS constraints. In Amahl's grammar, an illicit form such as [pʌɣl̩] will be eliminated as an optimal output by a dispreference for fricatives (motivated by a highly ranked constraint against fricatives: *FRIC).

The MARKEDNESS constraints in (8)(a-b) motivate stopping and velarization in Amahl's grammar. Satisfaction of these constraints also triggers violations to the conflicting FAITHFULNESS constraints given in (8)(c-d). My representation of the constraint which motivates velarization as *[COR][LAT] is contra to previous forms of this constraint, including *dl in Dinnsen and McGarrity (2004) and *tl in Wolf (2008) and Jesney (2005). However, we saw in (1) that even coronal nasals are affected and both of these forms seem too restrictive to account for the broader general restriction against [CORONAL] + [LATERAL] sequences. Also, while Jesney (2005) specifically focuses on restricting the stridency of the fricative segments with *[+STRIDENT], the more general form of *FRIC effectively restricts the same segments in this grammar and is demonstrably active in other early grammars.

(8) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. *[COR][LAT]: assign one violation mark for every sequence of [CORONAL] + [LATERAL]

b. *FRIC: assign one violation mark for every fricative

c. ID[PLACE]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [PLACE]

d. ID[CONT]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [CONT]

Minimally, the following relative rankings are necessary in Amahl's grammar. Stopping (i.e., /pʌ**z**l̩/ → [pʌ**d**l̩]) is motivated by a ranking of *FRIC » ID[CONT]. Velarization (i.e., /pʌ**d**l̩/ → [pʌ**g**l̩]) is motivated by a ranking of *[COR][LAT] » ID[PLACE]. Furthermore, since the grammatical output of /zl̩/ is [dl̩], it appears that violating *FRIC is worse than violating *[COR][LAT], and this implies a ranking of *FRIC » *[COR][LAT]. A general MARKEDNESS over FAITHFULNESS ranking, consistent with these phonological processes, is given in (9).

(9) *FRIC » *[COR][LAT] » ID[CONT], ID[PLACE]

Based on the MARKEDNESS and FAITHFULNESS constraints in (9), Harmonic Serialism generates the candidate chains in (10). When the input contains a coronal stop, velarization is the only harmonic change, as shown in (10)a. However, when the input contains a coronal fricative, multiple sequences of harmonically improving changes are possible, as shown in (10)b.

(10) Candidate chains for velarization and stopping:

a. <u>chains for input /pʌdl̩/</u>

<pʌdl̩> *no change*

<pʌdl̩, pʌgl̩> ✓ *velarize*

b. <u>chains for input /pʌzl̩/</u>

<pʌzl̩> *no change*

<pʌzl̩, pʌdl̩> ✓ *stopping*

<pʌzl̩, pʌɣl̩> *velarize*

<pʌzl̩, pʌɣl̩, pʌgl̩> *velarize; stopping*

<pʌzl̩, pʌdl̩, pʌgl̩> *stopping; velarize*

Although the constraint ranking in (9) selects the correct transparent output, it favors the two *convergent* candidates which exhibit a feeding chain shift, (d) and (e), rather than the correct opaque output, as shown in (11).[45]

(11) Standard OT ranking favoring a feeding over-application of velarization

/pʌdl̩/	*FRIC	*[COR][LAT]	ID[CONT]	ID[PLACE]
a <pʌdl̩>		*!		
b ☞<pʌdl̩, pʌgl̩>				*
/pʌzl̩/				
a <pʌzl̩>	*!	*		
b →<pʌzl̩, pʌdl̩>		*!	*	
c <pʌzl̩, pʌɣl̩>	*!			*
d ☜<pʌzl̩, pʌɣl̩, pʌgl̩>			*	*
e ☜<pʌzl̩, pʌdl̩, pʌgl̩>			*	*

[45] Candidate chains with identical output forms and which differ only in the order of process application are referred to as *convergent chains* in OT-CC.

2.3.2. Standard OT-CC failure for Amahl

The failure in (11) with a standard OT ranking indicates we need to evaluate the internal stages of the candidate chains. The logically possible PRECEDENCE constraints for ID[PLACE] and ID[CONT] are given in (12) and have the corresponding metaconstraints of ID[CONT] » PREC(ID[PLACE], ID[CONT]) and ID[PLACE] » PREC(ID[CONT], ID[PLACE]).

(12) *PREC(ID[PLACE], ID[CONT])*: assign a violation mark whenever

(a) a violation of ID[CONT] occurs and is not preceded by a violation of ID[PL], or

(b) a violation of ID[CONT] occurs and is followed by a violation of ID[PL]

PREC(ID[CONT], ID[PLACE]): assign a violation mark whenever

(a) a violation of ID[PL] occurs and is not preceded by a violation of ID[CONT], or

(b) a violation of ID[PL] occurs and is followed by a violation of ID[CONT]

As we can see based on unattested candidate selection in (13), simply including the PRECEDENCE constraints in a ranking which obeys the metaconstraints does not have the desired effect on optimal output selection, although the PRECEDENCE constraints do indicate preferences between candidates (d) and (e). In order for Amahl's grammar to select the correct opaque output, both metaconstraints must be violated and the two PRECEDENCE constraints must be relatively ranked with regard to each other, as illustrated in (14).

(13) Standard OT-CC tableau selecting incorrect opaque candidate

/pʌdl̩/	*Fric	*[cor] [lat]	Id [cont]	Prec (Id[pl], Id[cont])	Id [pl]	Prec (Id[cont], Id[pl])
a <pʌdl̩>		*!				
b ☞<pʌdl̩, pʌgl̩>					*	*a
/pʌzl̩/						
a <pʌzl̩>	*!	*				
b →<pʌzl̩, pʌdl̩>		*!	*	*a		
c <pʌzl̩, pʌɣl̩>	*!				*	*a
d ☜<pʌzl̩, pʌɣl̩, pʌgl̩>			*		*	*a*b
e <pʌzl̩, pʌdl̩, pʌgl̩>			*	*a!*b	*	

(14) Tableau selecting correct opaque output, but incorrect transparent output

/pʌdl̩/	*Fric	Prec (Id[cont], Id[pl])	Prec (Id[pl], Id[cont])	*[cor] [lat]	Id [cont]	Id [pl]
a ☜<pʌdl̩>				*		
b →<pʌdl̩, pʌgl̩>		*a!				*
/pʌzl̩/						
a <pʌzl̩>	*!			*		
b ☞<pʌzl̩, pʌdl̩>			*a	*	*	
c <pʌzl̩, pʌɣl̩>	*!	*a				*
d <pʌzl̩, pʌɣl̩, pʌgl̩>		*a!*b			*	*
e <pʌzl̩, pʌdl̩, pʌgl̩>			*a*b!		*	*

This violation of the metaconstraint to represent the *spontaneous* opacity exhibited by Amahl is independently argued by Wolf (2008) primarily for reasons of learnability (see also Tihonova 2009). Wolf suggests that the target language will not supply the positive evidence which is necessary to trigger key re-rankings related to non-target processes; thus, PRECEDENCE must initially be ranked above FAITHFULNESS. However, while we can see that violating the metaconstraints allows successful selection of the opaque candidate, a new problem arises with selection of the transparent candidate (contra analyses by Wolf (2008) and Tihonova (2009)). Where process application should be transparent, the most faithful candidate is selected. This of course is a consequence of PREC(ID[CONT], ID[PLACE]) now having a ranking that potentially allows it to rule out an attested natural language process (velarization) solely based on the ordering of FAITHFULNESS violations.[46]

The ranking paradox illustrated between the tableaux in (13) and (14) appears for several reasons. We want velarization to be blocked in environments derived by stopping, e.g., /pʌzl̩/ → [pʌdl̩] ↛ [pʌgl̩]. In order to get this, we need to rank PREC(ID[PLACE], ID[CONT]) and its (b)-clause (*no ID[PLACE] violation after ID[CONT] violation*) above the MARKEDNESS constraint *[COR][LAT], which motivates velarization. We also want stopping to be blocked in environments derived by velarization, e.g., /pʌzl̩/ → [pʌɣl̩] ↛ [pʌgl̩]. In order to get this we need to rank PREC(ID[CONT], ID[PLACE]) and its (b)-clause (*no ID[CONT] violation after ID[PLACE] violation*) above the MARKEDNESS constraint *[COR][LAT]. The tableau in (15) shows only (b)-clause violation assignments. This partial violation assignment results in successful selection of the correct transparent and opaque outputs.

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[46] This was the original motivation for McCarthy's inclusion of a metaconstraint ranking. However, Wolf (2008) argues that the metaconstraint requirement may in fact be *overly* restrictive for several attested nature language scenarios and lifting it could be theoretically desirable.

(15) Tableau showing only (b)-clause violations

/pʌdl̩/	*FRIC	PREC (ID[CONT], ID[PL])	PREC (ID[PL], ID[CONT])	*[COR] [LAT]	ID [CONT]	ID [PL]
a <pʌdl̩>				*!		
b ☞<pʌdl̩, pʌgl̩>						*
/pʌzl̩/						
a <pʌzl̩>	*!			*		
b ☞<pʌzl̩, pʌdl̩>				*	*	
c <pʌzl̩, pʌɣl̩>	*!					*
d <pʌzl̩, pʌɣl̩, pʌgl̩>		*b!			*	*
e <pʌzl̩, pʌdl̩, pʌgl̩>			*b!		*	*

However, the PRECEDENCE violation assignments in (15) create an incomplete representation since these constraints also assign another set of violations.[47] As minimally illustrated in the violation tableau in (17), the (a)-clause of PREC(ID[PLACE], ID[CONT]), that is *ID[CONT] violation must be preceded by ID[PLACE] violation*, must be ranked below *FRIC, the MARKEDNESS constraint that motivates stopping. Otherwise, stopping will be blocked in environments not derived by velarization, which is precisely where stopping is allowed, e.g., /pʌzl̩/ → [pʌdl̩]. Likewise, the (a)-clause of PREC(ID[CONT], ID[PLACE]), that is *ID[PLACE] violation must be preceded by ID[CONT] violation*, must be ranked below *[COR][LAT], the MARKEDNESS constraint that motivates velarization. Otherwise, velarization will be

[47] Assignment of just (a) or just (b)-clause constraints with a conjoined PRECEDENCE constraint is not a legitimate representation. Partial assignment is used here for illustrative purposes only.

blocked in environments not derived by stopping, which is precisely where velarization is allowed, e.g., /pʌdl̩/ → [pʌgl̩] and /pʌzl̩/ → [pʌɣl̩], as shown in (16).

(16) Tableau showing only (a)-clause constraint violations in conflicting ranking

/pʌdl̩/	*FRIC	PREC (ID[PL], ID[CONT])	*[COR] [LAT]	PREC (ID[CONT], ID[PL])	ID [CONT]	ID [PL]
a <pʌdl̩>			*			
b ☞<pʌdl̩, pʌgl̩>				*a!		*
/pʌzl̩/						
a <pʌzl̩>	*!		*			
b →<pʌzl̩, pʌdl̩>		*a!	*		*	
c <pʌzl̩, pʌɣl̩>	*!			*a		*
d ☜<pʌzl̩, pʌɣl̩, pʌgl̩>				*a!	*	*
e <pʌzl̩, pʌdl̩, pʌgl̩>		*a[48]			*	*

Furthermore, this crucial (a)-clause ranking directly conflicts with the previously established crucial (b)-clause ranking for PREC(ID[CONT], ID[PLACE]) in regard to *[COR][LAT]. Worse yet, while this ranking is successful in selecting the correct transparent output, we can see in (16) that it still fails to prefer opaque <pʌzl̩, pʌdl̩> over transparent <pʌzl̩, pʌɣl̩, pʌgl̩>, which was the primary motivation for lifting the metaconstraint. This situation is in no way improved by returning to the ranking which was successful with only (b)-clause violations since the (a)-clause violations are now problematic for selecting both the transparent and the opaque optimal outputs, as shown in (17) (see 💣s).

[48] This violation does not affect output selection when accompanied by the (b) violation, as in (14).

(17) Tableau showing only (a)-clause violations ranked above *[COR][LAT]

/pʌdl̩/	*FRIC	PREC (ID[CONT], ID[PL])	PREC (ID[PL], ID[CONT])	*[COR] [LAT]	ID [CONT]	ID [PL]
a ☜<pʌdl̩>				*		
b →<pʌdl̩, pʌgl̩>		💣*a!				*
/pʌzl̩/						
a <pʌzl̩>	*!			*		
b →<pʌzl̩, pʌdl̩>			💣*a	*!	*	
c <pʌzl̩, pʌɣl̩>	*!	*a				*
d <pʌzl̩, pʌɣl̩, pʌgl̩>		*a!			*	*
e ☜<pʌzl̩, pʌdl̩, pʌgl̩>			*a		*	*

Between the tableaux in (16) and (17) we can see that the (a)-clause violations will always fail to select the correct opaque output. A ranking of *FRIC » PREC(ID[CONT], ID[PLACE]) » PREC(ID[PLACE], ID[CONT]) » *[COR][LAT] is necessary for correct opaque candidate selection, but a conflicting ranking of *FRIC » PREC(ID[CONT], ID[PLACE]) » *[COR][LAT] » PREC(ID[PLACE], ID[CONT]) is necessary for correct transparent candidate selection.

A clear illustration of the ranking paradox generated by the conjoined-clause PRECEDENCE constraints in (14) can be seen in a comparative tableau using recursive constraint demotion. On the first pass, *FRIC receives the highest ranking. However, on the next pass RCD will crash since all of the remaining constraints will have at least one L undominated by a W.

(18) Comparative tableau highlighting ranking inconsistencies

W~L	*Fric	Prec (Id[cont], Id[pl])	Prec (Id[pl], Id[cont])	*[cor] [lat]	Id [cont]	Id [pl]
<pʌdl̩, pʌgl̩>~ <pʌdl̩>	(0~0)	💣L (1~0)	(0~0)	W (0~1)	(0~0)	L (1~0)
<pʌzl̩, pʌdl̩>~ <pʌzl̩>	W (0~1)	(0~0)	L (1~0)	(1~1)	L (1~0)	(0~0)
<pʌzl̩, pʌdl̩>~ <pʌzl̩, pʌdl̩, pʌgl̩>	(0~0)	(0~0)	W (1~2)	L (1~0)	(1~1)	W (0~1)
<pʌzl̩, pʌdl̩>~ <pʌzl̩, pʌɣl̩, pʌgl̩>	(0~0)	W (0~2)	L (1~0)	💣L (1~0)	(1~1)	W (0~1)
<pʌzl̩, pʌdl̩>~ <pʌzl̩, pʌɣl̩>	W (0~1)	W (0~1)	L (1~0)	L (1~0)	L (1~0)	W (0~1)

We can see that any ranking, with or without the Precedence constraints, will result in Ls that are undominated by Ws (see 💣s in (18)). Any successful ranking would require the (b)-clauses to be highly ranked and the (a)-clauses to be lowly ranked and this indicates that the orderings for Faithfulness violations may be acting independently. This independent activity motivates splitting the Precedence clauses into individual constraints that only assess a single sequence of violation assignments. Following Wolf (2011), the Precedence constraints in (12) can be split into the individually rankable (a) and (b)-clause constraints in (19) and (20).

(19) Prec(Id[place], Id[cont]) splits into:

(a) Id[pl]←Id[cont]: Id[cont] violation must be preceded by Id[pl] violation

(b) *Id[cont]-then-Id[pl]: no Id[pl] violation after Id[cont] violation

(20) PREC(ID[CONT], ID[PLACE]) splits into:

(a) ID[CONT]←ID[PL]: ID[PL] violation must be preceded by ID[CONT] violation

(b) *ID[PL]-THEN-ID[CONT]: no ID[CONT] violation after ID[PL] violation

We can again use recursive constraint demotion to determine if a consistent ranking is possible once the PRECEDENCE constraints have been split, as illustrated in (21). Here, *FRIC, *ID[CONT]-THEN-ID[PLACE] and *ID[PLACE]-THEN-ID[CONT] all have only Ws and receive a high ranking during the first RCD pass. The next pass provides the final W over the remaining undominated Ls by ranking *[COR][LAT] above the FAITHFULNESS constraints and the (a)-clause PRECEDENCE constraints. Since all losing candidates can now be eliminated, this comparative tableau ranking is successful.

(21) Comparative tableau with split PRECEDENCE constraints (after RCD)

W~L	*FRIC	*ID[P] -THEN- ID[C]	*ID[C] -THEN- ID[P]	*[COR] [LAT]	ID[C]	ID[P]	ID[C] ← ID[P]	ID[P] ← ID[C]
<pʌdl̩, pʌgl̩>~ <pʌdl̩>	(0~0)	(0~0)	(0~0)	W (0~1)	(0~0)	L (1~0)	L (1~0)	(0~0)
<pʌzl̩, pʌdl̩>~ <pʌzl̩>	W (0~1)	(0~0)	(0~0)	(1~1)	L (1~0)	(0~0)	(0~0)	L (1~0)
<pʌzl̩, pʌdl̩>~ <pʌzl̩, pʌɣl̩>	W (0~1)	(0~0)	(0~0)	L (1~0)	L (1~0)	W (0~1)	W (0~1)	L (1~0)
<pʌzl̩, pʌdl̩>~ <pʌzl̩, pʌɣl̩, pʌgl̩>	(0~0)	W (0~1)	(0~0)	L (1~0)	(1~1)	W (0~1)	W (0~1)	L (1~0)
<pʌzl̩, pʌdl̩>~ <pʌzl̩, pʌdl̩, pʌgl̩>	(0~0)	(0~0)	W (0~1)	L (1~0)	(1~1)	W (0~1)	(0~0)	(1~1)

However, the constraint ranking representation in (21), which shows independent activity and individual ranking for the (a) and (b) PRECEDENCE constraint clauses, is successful regardless of the tableau format. For completeness, we can return to the earlier violation tableau format, as illustrated in (22).

(22) Violation tableau with split PRECEDENCE constraints

/pʌdl̩/	*FRIC	*ID[P] -THEN- ID[C]	*ID[C] -THEN- ID[P]	*[COR] [LAT]	ID[C]	ID[P]	ID[C] ← ID[P]	ID[P] ← ID[C]
a <pʌdl̩>				*!				
b ☞<pʌdl̩, pʌgl̩>						*	*a	
/pʌzl̩/								
a <pʌzl̩>	*!			*				
b ☞<pʌzl̩, pʌdl̩>				*	*			*a
c <pʌzl̩, pʌɣl̩>	*!					*	*a	
d <pʌzl̩, pʌɣl̩, pʌgl̩>		*b!			*	*	*a	
e <pʌzl̩, pʌdl̩, pʌgl̩>			*b!		*	*		*a

We can now return to the failed aspect of harmonically ranked IDENT constraints from (4) and show how an OT-CC grammar succeeds where this representation failed, as illustrated in (23). In (4) we saw that the relevant processes were *deletion* and *velarization*. These processes involve violations of the FAITHFULNESS constraints MAX and ID[PLACE] and we can represent this under OT-CC by including the split PRECEDENCE clause constraints, with vital rankings of the (b)-clause constraints *ID[P]-THEN-MAX and *MAX-THEN-ID[P] in (23).

(23) Violation tableau with split PRECEDENCE constraints

/pɪstl̩/	*FRIC	*ID[P] -THEN-MAX	*MAX -THEN-ID[P]	*[COR][LAT]	ID[C]	ID[P]	MAX ← ID[P]	ID[P] ← MAX
a <pɪstl̩>	*!			*				
b ☞<pɪstl̩, pɪtl̩>				*			*a	
c <pɪstl̩, pɪtl̩, pɪkl̩>			*b!				*a	
d <pɪstl̩, pɪskl̩, pɪkl̩>		*b!						*a

At this point, we have seen that both standard OT and standard OT-CC fail to fully represent this child's grammar. The OT-CC modifications required for this scenario, split PRECEDENCE constraints and lifting the required metaconstraint, clearly indicate that (contra predictions by Wolf 2008; Tihonova 2009; and Dinnsen *et al*. 2011) this child's opaque productions do not pattern the same as the adult Bedouin Arabic counterfeeding opacity introduced in chapter 1, which was straightforwardly accounted for under standard OT-CC.

Amahl's productions also cannot be classified as mutual counterfeeding, in spite of requiring the same modifications to OT-CC and sharing a similar requirement of simultaneous rather than sequential process application. The most significant difference between the opacity pattern for Amahl and the hypothetical mutual counterfeeding pattern in chapter 1 is in how the processes interact on the input form. In Amahl's productions, rather than mutually counterfeeding each other with simultaneous process application, simultaneous application simply limits the number of processes that can apply. Ultimately, Amahl's grammar appears to contain a counterfeeding pattern that is not derived through process ordering. This is a crucial distinction from the necessarily ordered counterfeeding opacity in Bedouin Arabic. Amahl's productions provide preliminary support for both the claim that opacity patterns not predicted by the original formulation of OT-CC do exist in natural language and the claim that the patterns of opacity that appear during early stages of acquisition are distinct from opacity in adult grammars.

2.3.3. Child chain shift from Velten (1943)

We can next apply a similar analysis to opaque productions by Joan (1;10 – 2;1) months), taken from a diary study by Velten (1943). As Joan moves into CVC syllable production, her grammar exhibits two phonological processes which potentially interact in word-final position: nasal segments are realized as voiced stops of the same place of articulation (denasalization) and voiced obstruents are regularly devoiced (devoicing).[49] Neither coda devoicing nor realization of nasal segments as voiced stops is directly motivated in the target language. Evidence of application of these phonological processes can be seen in the tokens given in (24).

(24) Production for Joan (Velten 1943:286-287)

a. nasal → voiced stop (denasalization)

[fub]	'swim'	[dab]	'jam'
[bud]	'spoon'	[wud]	'rain'

---

[49] While I focus on word-final position, Joan's application of these processes is actually much broader scope and extends to word-initial and word-medial as well as word-final.

b. voiced → voiceless (coda devoicing)

[duf]	'stove'	[zus]	'shoes'
[bat]	'bad'	[zuts]	'seeds'

c. voiceless → voiceless (no change to voiceless codas)

[zaf]	'laugh'	[zas]	'sauce'
[dut]	'coat'	[uts]	'oats'

The interaction of these two processes has the potential to form a chain shift of nasal > voiced > voiceless, e.g., /spu**n**/ → [bu**d**] → *[bu**t**], but while these processes appear to be highly productive, a full feeding sequence is unattested in her grammar. If the processes of denasalization and devoicing apply sequentially to an input form, there are two possible orders, as shown in (25) and (26).

(25) Denasalization happens first:	/spun/[50]	/bad/
denasalization	[bud]	*n/a*
devoicing	[but]	[bat]

(26) Devoicing happens first:	/spun/	/bad/
devoicing	[bun̥]	[bat]
denasalization	[but]	*n/a*

50 The phonological change of /sp/ → [b] is referred to as *coalescence* in child productions. See Gnanadesikan (2004) for further discussion on this phenomenon.

We can see in (25) and (26) that under a sequential ordering scenario, either possible ordered interaction between devoicing and denasalization results in an unattested feeding chain shift. Again, the results from these two ordered process applications provide early indication that this opacity cannot be true counterfeeding since either ordering results in a feeding interaction. However, if devoicing and denasalization apply simultaneously to the input form, and neither process can apply to a derived form at a later stage, the outputs are limited to the forms in (27).

(27) Simultaneous process application:

a. /spun/ → [bud] (UR meets structural description of denasalization)

↘ [bun̥] (UR meets structural description of coda devoicing)

b. /bad/ → [bat] (UR meets structural description of coda devoicing only)

Similar to the data for Amahl, the underlying representation for Joan in (27)a meets the structural description for more than one process and non-optimal forms are over-generated. But again, this is unproblematic since an illicit form such as [bun̥][51]

[51] While the form [bun̥] is unattested as an output, it is a legitimate element of a chain shift in Joan's grammar since it follows from a general process of coda devoicing. While voiceless nasals are non-target for English, nasal devoicing in coda position occurs in languages such as French and Angas.

will be eliminated in Joan's grammar by dispreference for nasals (motivated by a highly ranked constraint against nasals: *NAS).[52]

The MARKEDNESS constraints in (28)(a-b) motivate denasalization and coda devoicing in Joan's grammar. Satisfaction of these constraints also triggers violations to the conflicting FAITHFULNESS constraints given in (28)(c-d).

(28) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. *NAS: assign one violation mark for every [NASAL] segment
b. *CODA[VOI]: assign one violation mark for every voiced coda segment
c. ID[NAS]: assign one violation mark for every set of corresponding input-output segments which have different values for the feature [NAS]
d. ID[VOI]: assign one violation mark for every set of corresponding input-output segments which have different values for the feature [VOI]

Minimally, the following relative rankings are necessary in Joan's grammar. Denasalization (i.e., /spu**n**/ → [bu**d**]) is motivated by a ranking of *NAS » ID[NAS]. Coda devoicing (i.e., /ba**d**/ → [ba**t**]) is motivated by a ranking of *CODA[VOI] » ID[VOI]. A general MARKEDNESS over FAITHFULNESS ranking, consistent with these phonological changes, is given in (29).

[52] Weinberger observes that this may be due to highly marked voiceless nasals. However, under Constraint Compression (Waybright 2011, but see details in chapter 4), since nasals are generally prohibited in Joan's grammar, she may not make distinctions between voiced and voiceless nasals.

(29) *NAS, *CODA[VOI] » ID[NAS], ID[VOI]

Based on this ranking, Harmonic Serialism generates the candidate chains in (30). When the input contains a voiced coda stop, coda devoicing is the only harmonic change, as shown in (30)a. However, when the input contains a nasal, multiple sequences of harmonically improving changes are possible, as shown in (30)b.

(30) Candidate chains for denasalization and devoicing:

a. chains for input /bad/		b. chains for input /spun/[53]	
<bad>	*no change*	<bun>	*no change*
<bad, bat> ✓	*devoice*	<bun, bud> ✓	*denasal*
		<bun, bun̥>	*devoice*
		<bun, bud, but>	*denasal; devoice*
		<bun, bun̥, but>	*devoice; denasal*

These candidate chains are evaluated in the violation tableau in (31), which fails to select the correct output in the opaque scenario. Rather, we can see that this ranking displays equal preference for the convergent feeding candidate chains, (d) and (e).

[53] Since Joan's grammar allows fricatives (cf. (24)), a possible alternative might be /n/ → [z] for denasalization, with [z] → [s] for coda devoicing. However, this sequence of changes appears less motivated. These candidate chains would be eliminated in a manner similar to the elimination of the ones produced by /n/ → [d] and [d] → [t].

(31) Standard OT ranking favoring unattested feeding interactions

/bad/	*NAS	*CODA[VOI]	ID[NAS]	ID[VOI]
a <bad>		*!		
b ☞<bad, bat>				*
/spun/				
a <bun>	*!	*		
b →<bun, bud>		*!	*	
c <bun, bun̥>	*!			*
d ☜<bun, bud, but>			*	*
e ☜<bun, bun̥, but>			*	*

2.3.4. Modified OT-CC representation for Joan

Again, a standard OT failure indicates we need to evaluate the internal stages of the candidate chains. The logically possible PRECEDENCE constraints for ID[NASAL] and ID[VOICE] are given in (32) and have the corresponding metaconstraints of ID[VOI] » PREC(ID[NAS], ID[VOI]) and ID[NAS] » PREC(ID[VOI], ID[NAS]).

(32) *PREC(ID[NAS], ID[VOI])*: assign a violation mark whenever

(a) a violation of ID[VOI] occurs and is not preceded by a violation of ID[NAS], or

(b) a violation of ID[VOI] occurs and is followed by a violation of ID[NAS]

PREC(ID[VOI], ID[NAS]): assign a violation mark whenever

(a) a violation of ID[NAS] occurs and is not preceded by a violation of ID[VOI], or

(b) a violation of ID[NAS] occurs and is followed by a violation of ID[VOI]

Unsurprising at this point, the Precedence constraints do not effect optimal output selection when they obey the metaconstraints, as shown in (33). The only current advantage to including Precedence constraints is in highlighting distinctions between candidate chains (d) and (e) that are not visible under standard OT.

(33) Standard OT-CC tableau selecting incorrect opaque candidate

/bad/	*Nas	*Coda [voi]	Id [nas]	Prec (Id[voi], Id[nas])	Id [voi]	Prec (Id[nas], Id[voi])
a <bad>		*!				
b ☞<bad, bat>					*	*a
/spun/						
a <bun>	*!	*				
b →<bun, bud>		*!	*	*a		
c <bun, bun̥>	*!				*	*a
d <bun, bud, but>			*	*a*b!	*	
e ☜<bun, bun̥, but>			*		*	*a!*b

Similar to Amahl, in order to select the correct opaque output, both metaconstraints must be violated and the Precedence constraints ranked relative to each other, as shown in (34). However, we encounter precisely the same problem with failing to select the correct transparent output due to Prec(Id[nas], Id[voi])'s preference for the most faithful candidate. This Precedence constraint ranking again has the unintended consequence of ruling out an attested natural language process (coda devoicing) based on the ordering of Faithfulness violations.

(34) Tableau selecting incorrect candidate for transparent scenario

/bad/	*NAS	PREC (ID[NAS], ID[VOI])	PREC (ID[VOI], ID[NAS])	*CODA [VOI]	ID [NAS]	ID [VOI]
a ☜<bad>				*		
b →<bad, bat>		*a!				*
/spun/						
a <bun>	*!			*		
b ☞<bun, bud>			*a	*	*	
c <bun, bun̥>	*!	*a				*
d <bun, bud, but>			*a*b!		*	*
e <bun, bun̥, but>		*a!*b			*	*

The ranking paradox illustrated between the tableaux in (33) and (34) results from the conflict between blocking processes in derived environments and not blocking permitted processes based on violation ordering. We want devoicing to be blocked in environments derived by denasalization, e.g., /bun/ → [bud] ↛ [but]. In order to get this we need to rank PREC(ID[VOI], ID[NAS]) and its (b)-clause of '*no ID[VOI] violation after ID[NAS] violation*' requirement above the MARKEDNESS constraint *CODA[VOI], which motivates devoicing. We also want denasalization to be blocked in environments derived by coda devoicing, e.g., /bun/ → [bun̥] ↛ [but]. In order to get this we need to rank PREC(ID[NAS], ID[VOI]) and its (b)-clause of '*no ID[NAS] violation after ID[VOI] violation*' requirement above the MARKEDNESS constraint *CODA[VOI]. The tableau in (35) shows only (b)-clause violation assignments and this partial violation assignment selects both correct outputs.

(35) Tableau showing only (b)-clause constraint violations

/bad/	*NAS	PREC (ID[NAS], ID[VOI])	PREC (ID[VOI], ID[NAS])	*CODA [VOI]	ID [NAS]	ID [VOI]
a <bad>				*!		
b ☞<bad, bat>						*
/spun/						
a <bun>	*!			*		
b ☞<bun, bud>				*	*	
c <bun, bun̥>	*!					*
d <bun, bud, but>			*b!		*	*
e <bun, bun̥, but>		*b!			*	*

Of course, the PRECEDENCE violation assignments in (15) provide an incomplete representation since the ranking conflict lies with the other required set of violations assigned by these constraints. The (a)-clause of PREC(ID[VOI], ID[NAS]), that is, the '*ID[NAS] violation must be preceded by ID[VOI] violation*' requirement, must be ranked below *NAS, the MARKEDNESS constraint that motivates denasalization. Otherwise, denasalization will be blocked in environments not derived by devoicing, which is precisely where denasalization is allowed, e.g., /bun/ → [bud]. Additionally, the (a)-clause of PREC(ID[NAS], ID[VOI]), that is, the '*ID[VOI] violation must be preceded by ID[NAS] violation*' requirement, must be ranked below *CODA[VOI]. Otherwise, coda devoicing will be blocked in environments not derived by denasalization, which is precisely where coda devoicing is allowed, e.g., /bad/ → [bat] (also, /bun/ → [bun̥]). Again, we can see that this crucial (a)-clause ranking directly conflicts with the previously established crucial (b)-clause ranking for PREC(ID[NAS], ID[VOI]) in regard to *CODA[VOI]. The minimally necessary ranking for the (a)-clause portion of the PRECEDENCE constraints for selection of the correct transparent output is shown in (36). In spite of violating both metaconstraints, this ranking still fails to prefer opaque <bun, bud> over transparent <bun, bun̥, but>.

(36) Tableau showing only (a)-clause constraint violations

/bad/	*NAS	PREC (ID[VOI], ID[NAS])	*CODA [VOI]	PREC (ID[NAS], ID[VOI])	ID [NAS]	ID [VOI]
a <bad>			*			
b ☞<bad, bat>				*a!		*
/spun/						
a <bun>	*!		*			
b →<bun, bud>		*a	*!		*	
c <bun, bun̥>	*!			*a		*
d <bun, bud, but>		*a			*	*
e ☜<bun, bun̥, but>				*a!	*	*

The tableaux in (35) and (36) illustrate that the (a)-clause violations in Joan's grammar will always fail to select the opaque output. We again have a paradox where a ranking of *NAS » PREC(ID[NAS], ID[VOI]) » PREC(ID[VOI], ID[NAS]) » *CODA[VOI] is necessary to select the correct opaque output, but this ranking conflicts with the required ranking of *NAS » PREC(ID[NAS], ID[VOI]) » *CODA[VOI] » PREC(ID[VOI], ID[NAS]) for selecting the correct transparent output. The ranking paradox between the tableaux in (35) and (36) can also be illustrated with a comparative tableau using recursive constraint demotion as in (37). *NAS has only

Ws and receives a high ranking on the first RCD pass. However, RCD crashes on the next pass since any ranking for the remaining constraints (with or without PRECEDENCE constraints) will result in Ls undominated by Ws (see 💣s).

(37) Comparative tableau highlighting ranking inconsistencies

W~L	*NAS	PREC (ID[VOI], ID[NAS])	PREC (ID[NAS], ID[VOI])	*CODA [VOI]	ID [NAS]	ID [VOI]
<bad, bat>~ <bad>	(0~0)	(0~0)	💣L (1~0)	W (0~1)	(0~0)	L (1~0)
<bun, bud>~ <bun>	W (0~1)	L (1~0)	(0~0)	(1~1)	L (1~0)	(0~0)
<bun, bud>~ <bun, bun̥>	W (0~1)	L (1~0)	W (0~1)	L (1~0)	(L (1~0)	W (0~1)
<bun, bud>~ <bun, bud, but>	(0~0)	W (1~2)	(0~0)	L (1~0)	(1~1)	W (0~1)
<bun, bud>~ <bun, bun̥, but>	(0~0)	💣L (1~0)	W (0~2)	💣L (1~0)	(1~1)	W (0~1)

Failure to find a possible consistent ranking here again indicates that these two processes are occurring independently and this provides motivation for splitting the PRECEDENCE constraints into individually rankable (a) and (b)-clause constraints. The PRECEDENCE constraints in (32) can be split into the constraints in (38) and (39).

(38) PREC(ID[NAS], ID[VOI]) splits into:

(a) ID[NAS]←ID[VOI]: ID[VOI] violation must be preceded by ID[NAS] violation

(b) *ID[VOI]-THEN-ID[NAS]: no ID[NAS] violation after ID[VOI] violation

(39) Prec(Id[voi], Id[nas]) splits into:

(a) Id[voi]←Id[nas]: Id[nas] violation must be preceded by Id[voi] violation

(b) *Id[nas]-then-Id[voi]: no Id[voi] violation after Id[nas] violation

We can test for a consistent ranking with the split Precedence constraints by using RCD in a comparative tableau, as shown in (40).

(40) Ranked comparative tableau with split Precedence constraints

W~L	*Nas	*Id[N] -then- Id[V]	*Id[V] -then- Id[N]	*Coda [voi]	Id [voi]	Id [nas]	Id[N] ← Id[V]	Id[V] ← Id[N]
<bad, bat>~ <bad>	(0~0)	(0~0)	(0~0)	W (0~1)	L (1~0)	(0~0)	L (1~0)	W (0~1)
<bun, bud>~ <bun>	W (0~1)	(0~0)	(0~0)	(1~1)	(0~0)	L (1~0)	(0~0)	L (1~0)
<bun, bud>~ <bun, bun̥>	W (0~1)	(0~0)	(0~0)	L (1~0)	W (0~1)	L (1~0)	W (0~1)	L (1~0)
<bun, bud>~ <bun, bud, but>	(0~0)	W (0~1)	(0~0)	L (1~0)	W (0~1)	(1~1)	(0~0)	(1~1)
<bun, bud>~ <bun, bun̥, but>	(0~0)	(0~0)	W (0~1)	L (1~0)	W (0~1)	(1~1)	W (0~1)	L (1~0)

On the first pass, *Nas, *Id[nasal]-then-Id[voice] and Id[voice]-then-Id[nasal] all have only Ws and receive an undominated ranking. This automatically maintains the crucial ranking of *Nas » Id[nas]. Only one row still requires a W and we can get this on the second pass with *Coda[voi]. At this point, all Ls have a W to the left, indicating a consistent ranking which can eliminate all losing candidates. The relative ranking of the remaining constraints does not affect optimal output selection. This separate activity for the (a) and (b)-clause constraints, can also be successfully illustrated in a violation tableau, as in (41).

(41) Violation tableau with split PRECEDENCE constraints

/bad/	*NAS	*ID[N] -THEN- ID[V]	*ID[V] -THEN- ID[N]	*CODA [VOI]	ID [NAS]	ID [VOI]	ID[N] ← ID[V]	ID[V] ← ID[N]
a <bad>				*!				
b ☞<bad, bat>						*	*a	
/spun/								
a <bun>	*!			*				
b ☞<bun, bud>				*	*			*a
c <bun, bun̥>	*!					*	*a	
d <bun, bud, but>		*b!			*	*		*a
e <bun, bun̥, but>			*b!		*	*	*a	

We can see at this point that Joan's opaque productions are neither adult-like counterfeeding (Kiparsky 1971) nor mutual counterfeeding (Wolf 2011). Recall from chapter 1 that the adult counterfeeding required no modifications to standard OT-CC. However, like mutual counterfeeding, Joan's opaque productions require the OT-CC modifications of lifting the metaconstraint and splitting the PRECEDENCE clauses into individually rankable constraints. Like Amahl, Joan's grammar contains an under-application pattern that is not derived through process ordering, but driven by simultaneous process application (i.e., non-ordered). The required differences between treatment for attested adult, theoretical adult, and attested child under-application interactions under OT-CC are summarized in Table **1.**

Table 1: Summary of *under-application* interactions and treatment

	ordered counterfeeding	*mutual counterfeeding*	*non-ordered counterfeeding*
PRECEDENCE clauses	Conjoined	Split	split
metaconstraint	Obeyed	Violated	violated
processes application	Sequential	simultaneous	simultaneous

2.4. Non-ordered over-application opacity

Although under-application opacity appears to be prevalent in early child developmental stages (Velten 1943; Smith 1973; Cho and Lee 2003; Ettlinger 2009), an equivalent form of over-application opacity is notably scarce in early child developmental stages. In general, this is unsurprising since the imbalance between over-application and under-application opacity in documented child productions corresponds with typological patterns for opacity in mature grammars, where counterbleeding is less frequent than counterfeeding.[54] Similarly, the relatively common occurrence of chain shifts in child production corresponds to typological preferences for counterfeeding occurring more frequently in natural language.

[54] This unequal ratio between counterfeeding and counterbleeding can also be seen in children with phonological delays as seen in the documented cases of child opacity by the research team of the Learnability Project at Indiana University. These phonologically delayed productions are analyzed and contrasted with early child productions in chapter 3.

2.4.1. Child opacity from Barlow and Keare (2008)

However, at least some evidence for child over-application opacity does appear to occur and one such case can be seen in an unpublished paper by Barlow and Keare (2008; see also Barlow 2003).[55] They look at opaque productions in child 1 (age 2;5) whose grammar contains the phonological processes of *vowel lengthening* before voiced codas and *coda devoicing* in word-final position. While vowel lengthening before voiced codas is target-like for English, it can be considered non-target in this child's grammar since it is appears before surface voiceless consonants and when the underlying coda has been reanalyzed as an onset in the diminutive form. These broader scope non-target applications of a target-like phonological process make it generally non-target-like. Final coda devoicing is also non-target for English. Phonological process application can be seen in the tokens in (42), which indicate the underlying voiced codas which trigger vowel lengthening.

(42) Vowel lengthening and coda devoicing (Barlow and Keare 2008; 84)

a. Vowel lengthening before underlying voiced coda

[mʌ:t] 'mud'	[dɔ:k] 'dog'	[tʰʌ:p] 'tub'
[dʌ:f] 'glove'	[tʃi:s] 'cheese'	[woʊ:p] 'robe'

b. Vowel lengthening before coda reanalysis as onset

[mʌ:di] 'mud (dim.)'	[dɔ:gi] 'dog (dim.)'
[gʌ:vi] 'glove (dim.)'	[tʃi:zi] 'cheese (dim.)'

[55] At the time of this study, this was the single case of early child over-application available.

c. No vowel lengthening before underlying voiceless coda

[wif]	‘leaf’	[dʌk]	‘duck’	[dʌki]	‘duckie (dim.)’
[ʤus]	‘juice’	[soʊp]	‘soap’	[soʊpi]	‘soap (dim.)’
		[fis]	‘fish’	[fisi]	‘fish (dim.)’

If these processes apply sequentially, there are two possible orders for underlying /dɔg/. If coda devoicing happens first, as shown in (43)a, then devoicing will bleed vowel lengthening since the resulting form no longer meets the structural description for vowel lengthening to apply. But if vowel lengthening happens first, as shown in (43)b, then lengthening will fail to bleed coda devoicing since the resulting form still meets the structural description for coda devoicing.

(43)	a. devoicing first:	/dɔg/	b. lengthening first:	/dɔg/
	coda devoicing	[dɔk]	*vowel lengthening*	[dɔːg]
	vowel lengthening	*n/a*	*coda devoicing*	[dɔːk]

However, the input /dɔg/ meets the structural description for vowel lengthening and coda devoicing, so if the processes are applied simultaneously, both will apply.

(44) Simultaneous process application: /dɔg/ → [dɔːk]

Importantly, we can see from (44) that the attested output is at least not *dependent* on sequential ordering. But the general rarity of marked phonological structures in in early child production makes an output like [dɔːk] still somewhat unexpected. This is largely due to the appearance of an unharmonious process application resulting in a long vowel before a voiced consonant, which is atypical for the target.

Following Barlow and Keare (2008), the MARKEDNESS constraints in (45)(a-b) motivate vowel lengthening and coda devoicing while satisfaction of these constraints violates the conflicting FAITHFULNESS constraints given in (45)(d-e).[56] We can also see that the obstruent is not devoiced in the diminutive, as in [dɔːgi]. This is expected under an assumption that the coda segment has been reanalyzed as an onset, which is motivated by the MARKEDNESS constraint ONSET, in (45)c.

(45) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. *V̆C[+VOI]: assign one violation mark for every short vowel before a voiced coda consonant; assign one violation mark for every long vowel elsewhere

b. *C[+VOI]#: assign one violation mark for every voiced obstruent coda segment

[56] Barlow and Keare (2008) suggest *V̆C̬, as a MARKEDNESS constraint which prohibits short vowel before voiced obstruents. However, such a constraint should also actively disprefer lengthening a vowel before a voiceless obstruent and they do not account for this in their representation, indicated by (💣*!) in tableau. Therefore, I follow Dinnsen *et al.* (2000) with the definition in (45)a and reformulate their constraint as *V̆C[+VOI]. They also use *C̬#, which I represent as *C[+VOI]#.

/dɔg/	*C̬#	*V̆C̬	ID[VOI]	PREC(ID[LEN], ID[VOI])	ID[LEN]
a <dɔg>	*!	*			
b <dɔg, dɔːg>	*!				*
c <dɔg, dɔk>			*	*a!	
d →<dɔg, dɔːg, dɔːk>		(💣*!)	*		*

c. ONSET: assign one violation mark for every vowel initial syllable[57]

d. ID[LENGTH]: assign one violation mark for every set of corresponding input-output segments which have different values for [LENGTH]

e. ID[VOI]: assign one violation mark for every set of corresponding input-output segments which have different values for the feature [VOI]

Minimally, the following relative rankings are necessary in child 1's grammar. Vowel lengthening (i.e., /d**ɔ**g/ → [d**ɔː**g]) is motivated by a ranking of *V̆C[+VOI] » ID[LEN]. Coda devoicing (i.e., /dɔ**g**/ → [dɔː**k**]) is motivated by a ranking of *C[+VOI]# » ID[VOI]. ONSET is never noticeably violated and receives an undominated ranking. The general MARKEDNESS » FAITHFULNESS ranking of ONSET, *V̆C[+VOI], *C[+VOI]# » ID[LEN], ID[VOI] in (46) is consistent with these phonological processes, but fails to select the opaque output.

(46) Failed standard OT representation

/dɔg/	ONSET	*C[+VOI]#	*V̆C[+VOI]	ID[VOI]	ID[LEN]
a [dɔg]		*!	*		
b [dɔːg]		*!			*
c ☜[dɔk]				*	
d →[dɔːk]			*!	*	*!

[57] Since ONSET does not affect CVC structure, it can be excluded for discussion of outputs in this form. In general, this process is only specifically referred to when it has potential to bleed vowel lengthening or coda devoicing, as it does for both in the structural description of /dɔg+i/.

Based on the constraint ranking in (46), Harmonic Serialism generates the candidate chains in (47) for the voiced coda input /dɔg/. For the voiceless coda input /dʌk/, there are no harmonic changes and the output is faithful to the input.

(47) Candidate chains for input /dɔg/:

<dɔg>	*no change*
<dɔg, dɔːg>	*vowel lengthening*
<dɔg, dɔk>	*coda devoicing*
<dɔg, dɔːg, dɔːk> ✓	*vowel lengthening; coda devoicing*

The logically possible PRECEDENCE constraints for ID[LENGTH] and ID[VOICE], which will evaluate the internal stages of these candidate chains, are given in (48) and have the corresponding metaconstraints of ID[VOI] » PREC(ID[LEN], ID[VOI]) and ID[LEN] » PREC(ID[VOI], ID[LEN]).

(48) *PREC(ID[LEN], ID[VOI])*: assign a violation mark whenever

(a) a violation of ID[VOI] occurs and is not preceded by a violation of ID[LEN], or

(b) a violation of ID[VOI] occurs and is followed by a violation of ID[LEN]

PREC(ID[VOI], ID[LEN]): assign a violation mark whenever

(a) a violation of ID[LEN] occurs and is not preceded by a violation of ID[VOI], or

(b) a violation of ID[LEN] occurs and is followed by a violation of ID[VOI]

Contra to the predictions of Barlow and Keare (2008), a PRECEDENCE constraint ranking which obeys the metaconstraint fails, as shown in (49).

(49) Tableau with PRECEDENCE constraints obeying metaconstraints

/dɔg/	*C# [+VOI]	*V̆C [+VOI]	ID[VOI]	PREC (ID[LEN], ID[VOI])	ID[LEN]	PREC (ID[VOI], ID[LEN])
a <dɔg>	*!	*				
b <dɔg, dɔːg>	*!				*	*a
c ☜<dɔg, dɔk>			*	*a		
d →<dɔg, dɔːg, dɔːk>		*!	*		*	*a*b

We can use a comparative tableau to determine if it is necessary to violate the metaconstraints and there is no other consistent ranking which could select the correct output while obeying the metaconstraints. As illustrated in (50), *C[+VOI]# and PREC(ID[LEN], ID[VOI]) have only Ws and received undominated rankings on the first pass. All Ls are dominated by a W at this point.

(50) Comparative tableau with consistent ranking (after RCD)

W~L	*C# [+VOI]	PREC (ID[LEN], ID[VOI])	*V̆C [+VOI]	PREC (ID[VOI], ID[LEN])	ID [VOI]	ID [LEN]
<dɔg, dɔːg, dɔːk>~ <dɔg>	W (0~1)	(0~0)	(1~1)	L (2~0)	L (1~0)	L (1~0)
<dɔg, dɔːg, dɔːk>~ <dɔg, dɔːg>	W (0~1)	(0~0)	L (1~0)	L (2~1)	L (1~0)	(1~1)
<dɔg, dɔːg, dɔːk>~ <dɔg, dɔk>	(0~0)	W (0~1)	L (1~0)	L (2~0)	(1~1)	L (1~0)

While we can find a consistent ranking with a comparative tableau, it is also clear that it is necessary to violate the metaconstraint in this grammar. The ranking in (50) can also be recreated in the violation tableau in (51).

(51) Violation tableau with Precedence constraints violating metaconstraints

/dɔg/	*C# [+voi]	Prec (Id[len], Id[voi])	*V̆C [+voi]	Prec (Id[voi], Id[len])	Id [voi]	Id [len]
a <dɔg>	*!		*			
b <dɔg, dɔːg>	*!			*a		*
c <dɔg, dɔk>		*a!			*	
d ☞<dɔg, dɔːg, dɔːk>			*	*a*b	*	*

Thus, similar to Wolf's mutual counterbleeding example in chapter 1, lifting the required metaconstraint successfully represents this child's over-application opacity so far. Recall that lifting the metaconstraint was also a necessary part of the representation for the simultaneous grammar under-application scenarios in §2.3.

The remaining opacity in the data in (42) we need to account for is vowel lengthening in the diminutive forms, such as [dɔːgi]. Since vowel lengthening does occur, it seems reasonable to assume that the voiced obstruent is an underlying coda and the marker /i/ an underlying onsetless syllable. The diminutive forms are presumed to have an underlying coda which is reanalyzed as an output onset through re-syllabification, motivated by Onset. However, the sequential conflict between re-syllabification and coda triggered vowel lengthening disappears under simultaneous application. The underlying form /dɔg+i/ meets the structural description for both, so both apply, producing the output in (52).

(52) Simultaneous process application: /dɔg+i/ → [dɔːgi]

Since the structural description of /dɔg+i/ allows three MARKEDNESS processes to apply (lengthening, coda devoicing and re-syllabification) we can see that the output in (52) is still missing one. Both [dɔːgi] and [dɔːki] can result from simultaneous application of the relevant MARKEDNESS processes. However, we can see in (53) that [dɔːgi] will always be considered more optimal under this grammar since [dɔːki] incurs an ID[VOI] violation that [dɔːgi] does not (i.e. [dɔːki] is harmonically bound by [dɔːgi] and will never win). Thus, this scenario is also successful under the violated metaconstraint grammar in (51).

(53) Tableau with PRECEDENCE constraints violating the metaconstraints

/dɔg+i/	ONSET	*C# [+VOI]	PREC (ID[LEN], ID[VOI])	*V̆C [+VOI]	PREC (ID[VOI], ID[LEN])	ID [VOI]	ID [LEN]
a <dɔg.i>	*!	*		*			
b☞<dɔg.i, dɔː.gi>				*	*a		*
c <dɔg.i, dɔ.ki>			*a!			*	
d <dɔg.i, dɔː.ki>				*	*a	*!	*

We have seen that the failed standard OT-CC representation in (49) indicates that this child over-application opacity is not the same as the Tiberian Hebrew over-application (i.e., counterbleeding) opacity introduced in chapter 1, which was straightforwardly accounted for under standard OT-CC. Furthermore, while this over-application opacity shares the simultaneous interaction aspect of mutual counterbleeding, there are some non-trivial differences. The most obvious is that these processes do not mutually fail to bleed one another. We saw in (43) that no ordering of vowel lengthening will bleed (or fail to bleed) coda devoicing. Thus, this pattern of opacity is more comparable to the child non-ordered pattern seen in §2.3. The required differences in treatment for attested adult, theoretical adult, and attested child over-application interactions under OT-CC are summarized in Table **2.** However, I discuss some additional important differences in the next section.

Table 2: Summary of *over-application* interactions and treatment

	ordered counterbleeding	*mutual counterbleeding*	*non-ordered counterbleeding*
PRECEDENCE clauses	conjoined	conjoined	(possibly split)
metaconstraint	obeyed	violated	violated
processes application	sequential	simultaneous	simultaneous

2.4.2. The nature of simultaneous over-application

Although the adult opacity typological preferences mentioned in chapter 1 appear to correspond with the rarity of over-application production in studies of early child acquisition, I would like to suggest that the scarcity of this type of opacity in these grammars stems from simultaneous rather than sequential process application. We saw that the under-application opacity exhibited by Amahl and Joan was driven by simultaneous application, and legitimate output forms were limited to those where a process could act on the underlying representation. However, in general, under-application opacity (e.g. ordered or non-ordered counterfeeding) is less dependent on a specific sequence as it is keeping a process from applying in a particular environment. By contrast, we have seen that over-application, such as counterbleeding, opacity is *highly* dependent on a specific sequential application which will allow both processes to apply. Recall from chapter 1 that adult counterbleeding required the PRECEDENCE (a)-clause violations (i.e., the clause that requires a violation must be *preceded* by another violation) for selection of the optimal output form. But as we saw in §2.3, the insurmountable problem for conjoined PRECEDENCE constraints with child opacity was the presence of these same (a)-clause violations. Where the adult grammars require a specific ordering, the child grammars fail under it. This also raises questions regarding the role of (a)-clause violations in the *simultaneous* grammar from (51), recreated here as (54).

(54) *C[+VOI]#, PREC(ID[L], ID[V]) » *V̆C[+VOI] » PREC(ID[V], ID[L]) » ID[VOI], ID[LEN]

We saw in (51) that the violation of PREC(ID[LEN], ID[VOI]) is indeed required to eliminate candidate <dɔg, dɔk> where coda devoicing must happen first. But we can also see that although this constraint prefers a sequence of vowel lengthening followed by coda devoicing, as opposed to the reverse sequence, it is not necessarily problematic our child's grammar since it has little to say in the *absence* of a particular sequence. The only real problem for our simultaneous grammar would be if we needed an (a)-clause violation to *prefer* a particular sequence rather than just *eliminate* a particular sequence. Also, while this over-application scenario does not force us to utilize split PRECEDENCE constraints like the child under-application scenarios in §2.3, a single (a)-clause violation assignment for the relevant constraint PREC(ID[LEN], ID[VOI]) does not *conflict* with independent activity.

In general, a child over-application scenario driven by simultaneous process application would need to include the following conditions: two MARKEDNESS » FAITHFULNESS relationships such that M_1 » F_1 and M_2 » F_2, but preferably M_1 » M_2 (although this falls out of M_2, PREC(F_2, F_1) » M_2) and crucially M_2 » F_1, for an overall ranking of M_1 » M_2 » F_1, F_2. We have just such a ranking in (54), i.e., *C[+VOI]# » *V̆C[+VOI] » ID[VOI], ID[LEN]. The importance of this ranking comes from forcing PREC(F_2, F_1) to participate in a ranking of PREC(F_2, F_1) » M_2, (i.e., PREC(ID[LEN], ID[VOI]) » *V̆C[+VOI]) thereby transitively dominating F_1 (ID[VOI] here) and violating the metaconstraint of F_1 » PREC(F_2, F_1). The crucial PRECEDENCE violations are of course the (a)-clause violations of PREC(F_2, F_1), and the ranking of PREC(F_1, F_2) is not significant as long as it is below PREC(F_2, F_1). However, we have seen that this simultaneous over-application leads to seemingly unharmoniously formed outputs like [dɔːk] and [dɔːgi]. As such, it appears to offer additional support for claims that this particular type of process interaction is expected to be rare. Furthermore, we still can predict that adult-like counterbleeding opacity will be *restricted* during early acquisition while sequential application is unavailable.

2.5. Conclusion

At this point, we have seen that opaque productions in early child acquisition are problematic for both standard OT and standard OT-CC and that both frameworks favor similar incorrect output candidates. However, we have also seen that the particular way child opacity fails under OT-CC serves to highlight fundamental distinctions, particularly in terms of the required OT-CC modifications of a lifted metaconstraint and split PRECECENCE clauses. I distinguish the transient child opacity as *non-ordered* since it directly contrasts with the strictly *ordered* opacity we saw in the adult grammars in chapter1. The crucial differences between child non-ordered opacity and adult ordered opacity result from two primary sources.

One significant difference we have already seen is that, unlike the sequential process ordering of adult opacity (Kiparsky 1973, McCarthy 1999), early child acquisition opacity results from simultaneous process application. A sequential restriction on child process application corresponds to aspects of studies on articulatory limitations, which claim that children have restricted ability to plan complex movements or movement sequences (Fletcher 1992). Also unlike adult opacity, where PRECEDENCE constraints can potentially favor particular orderings of FAITHFULNESS constraint violations, in child opacity, we have seen that the role of PRECEDENCE constraints is merely to eliminate candidate chains that require specific violation orderings in early acquisition grammars. Because PRECEDENCE clauses represent the logically possible sequential process interactions, a non-sequential (i.e., simultaneous) grammar is predicted to fail when they must be conjoined.

For under-application opacity in particular, the type of violation assignment, whether sequential or simultaneous, is reflected in the successful form of the PRECEDENCE constraints. Simultaneous application is favored by success of the individual (b)-clause constraints, which merely restrict a violation of the FAITHFULNESS B-constraint from being followed by a violation of the FAITHFULNESS A-constraint. It also explains the overall failure of the (a)-clause constraints in these children's grammars since these constraints force a sequential ordering by insisting on a violation of the FAITHFULNESS A-constraint before a violation of the FAITHFULNESS B-constraint. Only when violations assignments can be ordered will the conjoined clause PRECEDENCE constraints be successful. When violation assignments are necessarily unordered, individually rankable clause constraints are required to reflect independent activity between restricting a specific sequential ordering and forcing a particular ordering. Importantly, while motivation for splitting the PRECEDENCE constraints is not as obvious with simultaneous over-application opacity, independent clause activity does not appear to conflict with it in any way. Therefore, a split-PRECEDENCE, lifted-metaconstraint grammar is capable of representing both forms of simultaneous process opacity in child acquisition.

A second significant difference between child and adult opacity stems from a more general contrast between how children and adults treat language inconsistencies. An artificial language study by Hudson Kam and Newport (2005) shows that adults and children acquire generalizations in a very different manner. Their results showed that the adults tended to reproduce generalizations veridically, such that the participants exposed to consistent patterns produced consistent patterns while participants exposed to inconsistency learned and reproduced that inconsistency rather than regularizing to make the language more consistent.[58] In contrast, the children tended to over-generalize and many of them regularized the language, regardless of inconsistent input, by imposing patterns that did not match the input.

Such systematicity in children extends beyond paradigm regularization and is reflected in the broader application of phonological processes. While markedness processes are highly context driven in adult grammars, they appear to be significantly less context-constrained in early child production. Broad-scope over-generalization also plays an important role in the nature of the active processes in child grammar by permitting non-target markedness processes during early acquisition stages. This wide-scope process application drives over-generation of output forms for children in early stages of acquisition, as seen in §2.3 and §2.4, through greater potential harmonic process application. I return to discussion of an additional source of the broad-scope non-target markedness in chapter 4 and show how differences between child and adult opacity are driven by initial state structure.

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[58] They also report that some kinds of probabilistic exposure did produce more regular behaviors in the adult participants. However, the tendency to over-generalize was always stronger in children.

Chapter 3:
Opacity Patterns Across Language Acquisition Scenarios

3.1. Introduction

The emergence of temporary chain shifts, such as those discussed in chapter 2, is well-documented during stages of both early typical first language acquisition (Smith 1973; Velten 1943, Cho and Lee 2003; Ettlinger 2009; among others) and phonologically delayed first language acquisition (Dinnsen and Barlow 1998; Dinnsen *et al*. 2000; Dinnsen *et al*. 2011; Dinnsen *et al*. 2013; among others). However, the emergence and disappearance of chain shifts during stages of language acquisition is not limited to first language (L1) acquisition. There is also a corresponding pattern of chain shifts emerging and subsequently disappearing during stages of adult second language (L2) acquisition (Cho and Lee 2000, 2003; Idsardi 2002; Eckman *et al*. 2003; Jesney 2005). Due to the transient nature of acquisition-specific opaque productions, they are often overlooked as a source of data for modeling opacity under theoretical extensions. However, opaque productions that only emerge during stages of language acquisition are particularly relevant for this study since they raise questions regarding the source and possible patterns of opacity within developing grammars. We also saw in chapter 2 that the unpredicted non-ordered opacity patterns were largely driven by simultaneous versus sequential ordering.

One significant question at this point is whether this non-ordered opacity pattern could simply be a temporary phenomenon of general language acquisition, regardless of whether it is L1 or L2. Since transient, and generally non-target, chain shifts emerge during both child L1- and adult L2-acquisition, we can make testable predictions regarding the nature of this opacity.[59] If the chain shifts emerging during adult developmental stages pattern like those in child developmental stages, then non-ordered counterfeeding may simply be an effect of the language acquisition process. On the other hand, if the adult L2 chain shifts can be analyzed with standard OT-CC, where the child L1 chain shifts were shown to fail in chapter 2, then adult chain shifts can be classified as typical adult ordered opacity. This would imply that a distinction between non-ordered and ordered opacity must result from factors beyond just the language acquisition process itself.

A second question is whether this opacity pattern distinction is separate from general acquisition and the divide more appropriately falls between adult (including NL and L2) opacity and child (including typical and delayed L1) opacity. If chain shifts from adult L2 data can be accounted for within standard OT-CC, but phonologically delayed L1-acquisition reveals non-ordered opacity patterns, and thus cannot be accounted for with standard OT-CC, then we can surmise that this

[59] These chain shifts typically disappear, although L2 learners may fossilize in this stage. Such fossilization contrasts with typical L1 acquisition since non-target chain shifts inevitably disappear during the acquisition process.

pattern is closely associated with L1-acquisition. However, if both adult L2 and phonologically delayed L1 opacity can be successfully accounted for with standard OT-CC, then the scope of non-ordered counterfeeding can be further narrowed and possibly even upwardly bound by chronological age since these children have non-overlapping age groups: the developmentally typical children are all less than 3;0 while the phonologically delayed children are all over 3;0.

In this chapter, I test these possible areas of distinctions by comparing OT-CC representations of /s/-based chain shift data from adult L2-acquisition, phonologically delayed L1-acquisition and early typical L1-acquisition. The purpose of focusing on /s/-based chain shifts for this comparison is primarily to establish the greatest amount of common ground between opaque productions across these populations. However, /s/-based chains shifts are also a highly representative form of the opaque productions which appear during language acquisition scenarios. While we saw in chapter 2 that Amahl and Joan exhibited somewhat idiosyncratic chain shifts (Macken 1980; Jesney 2005; Dinnsen *et al*. 2011; among others), in general, it appears that common chain shifts emerging during both early (Cho and Lee 2003) and delayed (Dinnsen and Barlow 1998; Dinnsen *et al*. 2011; Dinnsen *et al*. 2013) L1-acquisition involve /s/ in some way. Similarly, /s/-based chain shifts frequently emerge during stages of adult L2-acquisition (Eckman *et al*. 2003; Cho and Lee 2000; Idsardi 2002). However, in spite of /s/-based shifts spanning adult and child acquisition, treatment of /s/ varies significantly between these groups.

Crosslinguistic evidence suggests that /s/ is the least marked fricative (Battistella 1990), which in turn predicts it may be acquired earlier than other fricatives (Stoel-Gammon & Dunn 1985; Barlow 1997; Gierut 1999). However, late-acquisition of /s/ in English has also been reported (Smit, Hand, Freilinger, Bernthal and Bird (1990). The unmarked status of /s/ receives support in the treatment of adult L2 English learners. L1 Korean, Japanese and Latin American Spanish speakers substitute /s/ for non-L1 segments such as interdental fricatives (Eckman *et al.* 2003). In contrast to typical adult substitution *of* /s/ for more marked segments (Lombardi 2003), child chain shifts show substitutions *for* /s/, such as Korean L1 learners substituting /h/ for /s/ and English L1 children with phonological delays substituting /θ/ for /s/.[60] While the precise nature of differences between child and adult treatment of /s/ extends beyond the scope of this dissertation, a partial source may be MARKEDNESS constraint interactions emerging during re-ranking stages.[61] In particular, /s/ based phonologically delayed chain shifts can be shown to reflect specific differences in MARKEDNESS constraint rankings compared to those in adult grammars and I explore these MARKEDNESS ranking differences more fully in §3.4.2.

[60] In particular, this substitution is unexpected during L1 acquisition based on markedness of /θ/ vs. /s/. However, since it commonly occurs in phonologically delayed English acquisition, it may simply be a part of the generally atypical phonological behavior of these children (discussed further in §3.4).

[61] In general, differences between child and adult grammars can be traced to early MARKEDNESS » FAITHFULNESS rankings (Demuth 1995; Gnandesikan 1995, 2004; Pater 1997; Smolensky 1996; Tesar and Smolensky 1998; Jusczyk, Smolensky and Allocco 2002) compared to general FAITHFULNESS » MARKEDNESS rankings (Tesar and Smolensky 1998) for adults. However, ranking differences *within* these constraint classes are also natural consequence of acquisition based on constraint re-ranking.

The remainder of this chapter is organized in the following manner. In §3.2 I analyze two cases of /s/-based chain shifts that emerge during adult L2-acquisition and show their similarity to mature grammar counterfeeding with a standard OT-CC representation. The adult L2 data comes from Eckman *et al*. (2003), where L1 Korean and Japanese learners of L2 English exhibit *θ>s* and *s>ʃ*, but the feeding interaction of *θ>s>ʃ* is unattested. Similarly, L1 Latin American Spanish learners of L2 English exhibit *θ>s* and *s>z*, but *θ>s>z* is unattested. These adult chain shifts are contrasted with an OT-CC representation of a child /s/-based chain shift in §3.3. Data from a Korean L1 acquisition study by Cho and Lee (2003) show that *s>h* and *h>k*, but *s>h>k* is unattested. These opaque child productions cannot be represented with standard OT-CC and require the OT-CC modifications introduced in chapter 2. In §3.4 I look at opaque productions from studies of children with (phonologically) delayed development, specifically counterbleeding from Dinnsen *et al*. (2000) and counterfeeding chain shifts (*s>θ>f*) from Dinnsen *et al*. (2011). A standard OT-CC representation of these cases reveals that the opacity which emerges during delayed L1-acquisition is similar to adult grammar opacity. I conclude in §3.5 by discussing underlying differences between adult and child opacity patterns, as well as key differences between typical and delayed phonological development.

3.2. Adult L2-acquisition chain shifts

Evidence of two adult counterfeeding chain shifts involving /s/ comes from an English L2 study by Eckman, Elreyes and Iverson (2003), who primarily look at acquisition of phonemic contrasts in second languages. However, they also find forms of environmentally conditioned opacity which temporarily emerge during stages of L2-acquisition. These opaque adult L2 productions largely appear to be motivated by potential interaction between processes influenced by the L1 and processes influenced by general interlanguage movement toward unmarked structures (see Broselow, Chen and Wang (1998) for discussion on the *emergence of the unmarked* in second language acquisition).

3.2.1. L1 Korean and Japanese opacity in L2 English

Eckman *et al*. (2003) find that L1 Korean speakers substitute /s/ for the interdental fricative /θ/ in L2 English (see also Lee 2000; Cho and Lee 2000; Idsardi 2002). This results, for example, in an input such as *thank* being realized as [saŋk]. Additionally, these L2 learners have a process of palatalization before high front vowels, such as /ɪ/ and /i/, which can be traced to native language influence. Thus, an input such as /sɪŋk/ is realized as [ʃɪŋk]. These processes have the potential to interact in the feeding chain shift *θ>s>ʃ*. However, Eckman *et al*. find what they term *systematic blocking* of a possible substitution in the interlanguage grammar. For example, when /θ/ occurs before a high front vowel, as in *think*, the output is [sɪŋk] rather than [ʃɪŋk]. (See also discussion by Idsardi 2002, and Cho and Lee 2000 regarding this particular chain shift in L1-Korean L2-English.) This same chain shift pattern also occurs during L1-Japanese acquisition of L2-English.[62]

The MARKEDNESS constraints which motivate /θ/ → [s] and palatalization are given in (1)(a-b) and the conflicting FAITHFULNESS constraints are given in (1)(c-d).

(1) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. PAL: assign one violation mark for every non-palatal [+ANTERIOR] coronal segment preceding a high front vowel

b. *[DENT]: assign one violation mark for every segment with the feature [DENT]

c. ID[DENT]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [DENT]

d. ID[ANT]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [ANTERIOR]

Palatalization before high front vowels (i.e., /**s**ɪŋk/ → [**ʃ**ɪŋk]) is motivated by a ranking of PAL » ID[ANT], where ID[ANT] is violated to satisfy PAL. Loss of [DENTAL] (i.e., /**θ**ɪŋk / → [**s**ɪŋk]) is motivated by a ranking of *[DENT] » ID[DENT], where ID[DENT]is violated to satisfy *[DENT]. These rankings can be combined in the overall ranking of *[DENT] » ID[DENT], PAL » ID[ANT]. Based on this ranking, Harmonic

[62] Like the Korean L2 speakers, they produce *sink* as [ʃɪŋk], but *think* as [sɪŋk] rather than [ʃɪŋk]. Eckman *et al*. also note that one participant produced the phrase *sympathy theory* as [ʃɪmpasi sɪɹi] rather than [ʃɪmpaʃi ʃɪɹi]. However, this production is included somewhat ironically since they go on to claim that a Sympathy account cannot successfully analyze this derived environment opacity.

Serialism generates the candidate chains in (2). When the input contains a coronal fricative before /i/, palatalization is the only harmonic change, as in (2)a. However, when the input contains the interdental fricative /θ/ a sequence of harmonically improving changes is possible, as in (2)b.

(2) Candidate chains for palatalization and /θ/ → [s]:

a. <u>chains for input /sɪŋk/</u>		b. <u>chains for input /θɪŋk/</u>	
<sɪŋk>	*no change*	<θɪŋk>	*no change*
<sɪŋk, ʃɪŋk> ✓	*palatalization*	<θɪŋk, sɪŋk> ✓	*/θ/→[s]*
		<θɪŋk, sɪŋk, ʃɪŋk>	*palatalization; /θ/→[s]*

A standard OT representation can only select the correct transparent output and fails to select the correct opaque output, as illustrated in (3).

(3) Standard OT selecting transparent output but not opaque output

/sɪŋk/	*[DENT]	ID[DENT]	PAL	ID[ANT]
a <sɪŋk>			*!	
b ☞<sɪŋk, ʃɪŋk>				*
/θɪŋk/				
a <θɪŋk>	*!			
b →<θɪŋk, sɪŋk>		*	*	
c ☜<θɪŋk, sɪŋk, ʃɪŋk>		*		*

The PRECEDENCE constraints for ID[DENT] and ID[ANT], given in (4), can evaluate the internal stages of these candidate chains and have corresponding metaconstraints of ID[DENT] » PREC(ID[ANT], ID[DENT]) and ID[ANT] » PREC(ID[DENT], ID[ANT]).

(4) *PREC(ID[ANT], ID[DENT])*: assign a violation mark whenever

(a) a violation of ID[DEN] occurs and is not preceded by a violation of ID[ANT], or

(b) a violation of ID[DEN] occurs and is followed by a violation of ID[ANT]

PREC(ID[DENT], ID[ANT]): assign a violation mark whenever

(a) a violation of ID[ANT] occurs and is not preceded by a violation of ID[DEN], or

(b) a violation of ID[ANT] occurs and is followed by a violation of ID[DEN]

Similar to the adult Bedouin Arabic counterfeeding opacity in chapter 1, the L2 counterfeeding chain shift opacity for the L1 Korean and L1 Japanese English learners can also be analyzed with standard OT-CC, as shown in (5).

(5) Standard OT-CC successful transparent and opaque candidate selection

/sɪŋk/	*[DENT]	ID [DENT]	PREC (ID[ANT], ID[DENT])	PAL	ID [ANT]	PREC (ID[DENT], ID[ANT])
a <sɪŋk>				*!		
b ☞<sɪŋk, ʃɪŋk>					*	*a
/θɪŋk/						
a <θɪŋk>	*!					
b ☞<θɪŋk, sɪŋk>		*	*a	*		
c <θɪŋk, sɪŋk, ʃɪŋk>		*	*a*b!		*	*a

3.2.1. L1 Latin American Spanish opacity in L2 English

Additional evidence comes from native Latin American Spanish speakers learning L2 English, with similar patterns of θ-substitution, e.g., where /θ/ → [s], resulting in a word like *tooth* being pronounced [tus] (Eckman *et al*. 2003). These speakers also exhibit voice-assimilation, which can be traced to native language influence since /s/ and /z/ are in complementary distribution in many varieties of Latin American Spanish; e.g., [z] occurs before voiced consonants (/mismo/ → [mizmo] '*same*') and [s] occurs elsewhere (Zampini 1996). These processes have the potential to interact to form the feeding chain shift *θ>s>z*. For this study, Eckman *et al*. (2003) elicited production from three L1 Spanish subjects. They report that these English learners systematically voiced [s] before another voiced consonant and used [s] in words with [θ], however, a feeding interaction between these processes was unattested.[63] Where these speakers used [s] instead of /θ/, they did not voice the [s], regardless of the voicing environment. For words such as *clothbag*, these speakers produced [klɔsbæk] rather than *[klɔzbæk].

The MARKEDNESS constraints which motivate the phonological processes of voicing agreement and /θ/ → [s] are given in (6)(a-b), along with their conflicting FAITHFULNESS constraints in (6)(c-d).

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[63] Eckman *et al*. (2003) do not give examples of explicit L2 environmentally triggered voicing of /s/ other than the native language example (/mismo/ → [mizmo]). Therefore, the specific context for establishing voicing changes is absent and I follow them by representing the possible change sequences with segments only.

(6) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. AGREE[VOI]: assign one violation mark for every sequence of obstruents that does not have the same value for the feature [VOI]

b. *[DENT]: assign one violation mark for every segment with the feature [DENT]

c. ID[DENT]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [DENT]

d. ID[VOI]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [VOI]

Voicing assimilation before voiced consonants (i.e., /sb/ → [zb]) is motivated by a ranking of AGREE[VOI] » ID[VOI], where ID[VOI] is violated to satisfy AGREE[VOI]. Loss of [DENTAL] (i.e., /tu**θ**/ → [tu**s**]) is motivated by a ranking of *[DENT] » ID[DENT], where ID[DENT]is violated to satisfy *[DENT]. These rankings can be combined in the overall ranking of *[DENT] » ID[DENT], AGREE[VOI] » ID[VOI]. Based on this ranking, Harmonic Serialism generates the candidate chains in (7). When the input contains a sequence of C[-VOI]C[+VOI], voicing assimilation is the only harmonic change, as shown in (7)a. However, when the input contains the interdental fricative /θ/ preceding a voiced consonant, as shown in (7)b, it is possible to over-generate a sequence of harmonically improving changes, such as the unattested output of <klɔθbæk, klɔsbæk, klɔzbæk>.

(7) Candidate chains for voice-assimilation and /θ/ → [s]:

a. <u>chains for input /sC[+VOI]/</u>		b. <u>chains for input /θC[+VOI]/</u>	
<s>	*no change*	<θ>	*no change*
<s, z> ✓	*voice-assimilation*	<θ, s> ✓	*/θ/→[s]*
		<θ, s, z>	*/θ/→[s]; voice-assimilation*

It is also unsurprising at this point that a standard OT representation of this Spanish-English data can only select the correct transparent output and fails to select the correct opaque output, as illustrated in (8).

(8) Standard OT selecting transparent output but not opaque output

/s/	*[DENT]	ID[DENT]	AGREE[VOI]	ID[VOI]
a <s>			*!	
b ☞<s, z>				*
/θ/				
a <θ>	*!			
b →<θ, s>		*	*	
c ☜<θ, s, z>		*		*

Again, we need to evaluate the internal stages of these candidate chains to eliminate the feeding interaction. The PRECEDENCE constraints for ID[DENT] and ID[VOI] are given in (9) and have the corresponding metaconstraints of ID[DENT] » PREC(ID[VOI], ID[DENT]) and ID[VOI] » PREC(ID[DENT], ID[VOI]).

(9) PREC(ID[VOI], ID[DENT]): assign a violation mark whenever

(a) a violation of ID[DEN] occurs and is not preceded by a violation of ID[VOI], or

(b) a violation of ID[DEN] occurs and is followed by a violation of ID[VOI]

PREC(ID[DENT], ID[VOI]): assign a violation mark whenever

(a) a violation of ID[VOI] occurs and is not preceded by a violation of ID[DEN], or

(b) a violation of ID[VOI] occurs and is followed by a violation of ID[DEN]

Furthermore, as illustrated in (10) with the conjoined PRECEDENCE constraint in a ranking which obeys the metaconstraints, this Spanish-English L2 interlanguage counterfeeding opacity can also be analyzed with standard OT-CC.

(10) Standard OT-CC successful transparent and opaque candidate selection

/s/	*[DENT]	ID [DENT]	PREC (ID[VOI], ID[DENT])	AGREE [VOI]	ID [VOI]	PREC (ID[DENT], ID[VOI])
a <s>				*!		
b ☞<s, z>					*	*a
/θ/						
a <θ>	*!					
b ☞<θ, s>		*	*a	*		
c <θ, s, z>		*	*a*b!		*	*a

Similar to the child acquisition chain shifts in chapter 2, the L2 chain shifts for these native Japanese/Korean and Spanish speakers involve processes which are non-target for English. However, these L2 chain shifts contrast with those which emerge in early L1 productions in that at least one process is directly influenced by a mature grammar (i.e., the L1). Palatalization is a productive process for both Japanese and Korean, and voicing assimilation is similarly productive in Latin American Spanish. As such, they are likely transferred into the L2 with the same limited context application.

Additionally, the native inventories for Japanese, Korean and Latin American Spanish all lack the interdental fricative /θ/. L2-English substitution of relatively unmarked /s/ for marked /θ/ (Cho and Lee 2000; Idsardi 2002; Eckman *et al*. 2003) for speakers of these L1s corresponds to a cross-linguistic pattern of substitution for a marked segment. Substitution of /s/ for /θ/ (i.e., loss of the [DENTAL] feature) can be seen in a variety of L2 English learners with native inventories without this interdental fricative, such as German and Egyptian Arabic (Lombardi 2003: see also her discussion of /θ/ → [s] for L1 Russian and Hungarian in L2 English).

The native grammar influence and cross-linguistic preferences for unmarked segments appears to contrast significantly with the source of the phonological processes which appeared in the developing child grammars in chapter 2. These were not influenced by another grammar and did not even necessarily result in the use of segments that were cross-linguistically less marked. Thus, a more direct comparison between acquisition opacity in the child and adult populations can be made by comparing the /s/-based chain shifts which emerged in these adult L2 learners with representations of an /s/-based chain shift found in a Korean L1-acquisition study by Cho and Lee (2003) in the next section.

3.3. Early Korean L1-acquisition chain shift

While the specific phonological processes for the chain shifts found in the child acquisition studies introduced in chapter 2 may be idiosyncratic to these children, early L1 Korean productions reveal an /s/-based chain shift pattern involving interaction of phonological processes which occur across multiple children. The following chain shift data come from a Korean first language acquisition diary study of child S.H. by Cho and Lee (2003). They analyze this opacity under Comparative Markedness and I follow their treatment of these productions as the result of categorical and productive process interactions. Cho and Lee (2003) find the context independent phonological processes of /s/ → [h] and /h/ → [k]. The change of /s/ → [h] can be characterized as a loss of [CORONAL] place, or *decoronalizatio*n, while /h/ → [k] appears to primarily involve *stopping* (discussed further below). However, neither of these processes appears to be directly motivated by Korean.

(11) Child S.H. - age 1;7-2;0 (Cho and Lee 2003:492):[64]

a.	/s/ replaced by [h]	/sadari/	[hadadi]	‘ladder’
	(decoronalization)	/sagwa/	[huaga]	‘apple’
		/sat^{h}aŋ/	[hat’aŋ]	‘candy’

[64] The transcriptions from Cho and Lee (2003) have been partially modified to conform to standard IPA. Additionally, while I focus on the stopping that occurs in initial position, stopping also occurs in loss of aspiration, e.g., /^{h}/ becomes [’] (or [ˀ]). However, these are non-pulmonic ejectives that do not appear to participate in these particular chain shift processes.

b.	/h/ replaced by [k]	/hjudʒi/	[k’ogi]	‘tissue’
	(stopping)	/horaŋi/	[kəgəni]	‘tiger’
		/hobak/	[k’oba]	‘zucchini’
c.	/k/ produced	/k^{h}o/	[k’o]	‘nose’
	target-appropriately	/k^{h}ok’iri/	[k’ok’ii]	‘elephant’
		/kæguri/	[kak’ui]	‘frog’

The two possible sequential orders for the processes of decoronalization and stopping are shown in (12) If the ordering in (12)a happens, then decoronalization (/s/ → [h]) would feed stopping (/h/ → [k]). However, the resultant feeding interaction of *s>h>k* is not attested in this child’s production. Similarly, if the ordering in (12)b happens, it would produce the unattested feeding interaction of *s>t>ʔ*, where stopping (/s/ → [t]) feeds decoronalization (/t/ → [ʔ]).[65]

(12)	a. Decoronalization happens first:	/sat^{h}aŋ/	/hobak/
	decoronalization	[hat^{h}aŋ]	*n/a*
	stopping	[kat’aŋ]	[k’oba]
	b. Stopping happens first:	/sat^{h}aŋ/	/hobak/
	stopping	[tat’aŋ]	[k’oba]
	decoronalization	[ʔat’aŋ]	*n/a*

[65] Although it is possible that /s/ → [h] involves loss of the feature [STRIDENT], decoronalization of /t/ does not and could also result in [k]. However, /t/ → [ʔ] is more consistent with /s/ → [h].

It is clear that neither of the sequentially orderings in (12) can produce both attested outputs. Furthermore, since both orderings result in feeding interactions, we can see that such interactions cannot be classified as counterfeeding opacity. However, similar to the child opacity scenarios in chapter 2, if these processes apply simultaneously, the correct outputs are produced and limited to those in (13).

(13) Simultaneous rule application:

a. /sat^{h}aŋ/ → [hat'aŋ] (UR meets structural description for decoronalization)

↘ *[tat'aŋ] (UR meets structural description for stopping)

b. /hobak/ → [k'oba] (UR meets structural description of stopping)

3.3.1. Standard /s/-based L1 representations

The MARKEDNESS constraints in (14)(a-b) motivate stopping and decoronalization in child S.H.'s grammar and have the conflicting FAITHFULNESS constraints in (14)(c-d).

(14) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. *[COR]: assign one violation mark for every coronal segment

b. *FRIC: assign one violation mark for every fricative

c. ID[PLACE]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [PLACE]

d. ID[CONT]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [CONT]

Decoronalization (where a segment loses its [COR] feature, as in /s/ → [h]) is motivated by a ranking of *[COR] » ID[PLACE], where ID[PLACE] is violated to satisfy *[COR]. Stopping (i.e., /h/ → [k]) is minimally motivated by a ranking of *FRIC » ID[CONT], where ID[CONT] is violated to satisfy *FRIC, since this involves at least a change in continuance. A general MARKEDNESS » FAITHFULNESS ranking of *[COR], *FRIC » ID[PLACE], ID[CONT] is consistent with these phonological changes. Based on this ranking, Harmonic Serialism generates the general form candidate chains in (15). When the input contains an /h/, stopping is the only harmonically improving change and the output is a [k], as in (15)a. However, classifying /h/ → [k] as an incremental change requires some additional discussion. The approach I take here is to classify /h/ as having an unspecified place of articulation; therefore, there /h/ → [k] does not receive an ID[PLACE] violation, only an ID[CONT] violation.[66] When the input is /s/, a succession of harmonically improving changes are possible, as in (15)b. However, unlike /h/ → [k], /s/ → [h] only involves loss of [COR] place, which does not incur an ID[PLACE] violation since [PLACE] does not have a different value.

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[66] Following feature assignments in Roca & Johnson (1999) any [PLACE] feature for /h/ may be superfluous. And while /h/ → [k] appears similar to velarization in some respects, it falls short in terms of a change of place and therefore does not assign the same set of ID[PLACE] violations. Under this approach, /h/ → [ʔ] is an equally likely change, but may be disfavored by an early child acquisition preference of salient onsets since this process targets word initial segments here.

(15) Candidate chains for stopping and decoronalization: [67]

a. chains for input with /h/		b. chains for input with /s/	
<h>	*no change*	<s>	*no change*
<h, k> ✓	*stopping*	<s, h> ✓	*decoronalize*
		<s, t>	*stopping*
		<s, h, k>	*decoronalize*; *stopping*
		<s, t, ʔ>	*stopping*; *decoronalize*

We know that a standard OT ranking will prefer a feeding interaction in this scenario, resulting in a failure to select both the correct transparent and opaque outputs as optimal. Thus, it is necessary to evaluate the internal stages of the candidate chains in (15). The PRECEDENCE constraints for ID[PLACE] and ID[CONT] are given in (16) and have the corresponding metaconstraints of ID[CONT] » PREC(ID[PLACE], ID[CONT]) and ID[PLACE] » PREC(ID[CONT], ID[PLACE]).

(16) *PREC(ID[PLACE], ID[CONT])*: assign a violation mark whenever

(a) a violation of ID[CONT] occurs and is not preceded by a violation of ID[PL], or

(b) a violation of ID[CONT] occurs and is followed by a violation of ID[PL]

---

[67] While the nature of these phonological changes may generate additional candidates, those listed in (15) appear to be the most likely. Under Harmonic Serialism, candidate chains such as <h, ʔ, k> and <h, x, k> also appear possible. While I do not rule out the possibility of such chains, they may be over-generation of incremental changes for this grammar. However, even if these chains are generated, they will be eliminated by PRECEDENCE constraints due to ungrammatical orderings of ID[PLACE] and ID[CONT] violations. The chain <s, x, k> also appears possible, but is excluded in (15) since it explicitly invokes velarization. This candidate would also be eliminated by PRECEDENCE constraints.

PREC(ID[CONT], ID[PLACE]): assign a violation mark whenever

(a) a violation of ID[PL] occurs and is not preceded by a violation of ID[CONT], or

(b) a violation of ID[PL] occurs and is followed by a violation of ID[CONT]

Similar to the child opacity scenarios in chapter 2, when PRECEDENCE constraints obey the metaconstraints[68], they are ranked too low to effect correct output selection. When the metaconstraint rankings are violated, the correct opaque output is selected, but this success comes at the cost of selecting the most faithful output rather than the correct one in the transparent scenario, as shown in (17).

(17) OT-CC with violated metaconstraint: opaque, but not transparent success

/h/	*[COR]	PREC (ID[CONT], ID[PL])	PREC (ID[PL], ID[CONT])	*FRIC	ID [PLACE]	ID [CONT]
a ☜<h>				*		
b →<h, k>		*a!				*
/s/						
a <s>	*!			*		
b ☞<s, h>			*a	*	*[69]	
c <s, t>	*!	*a				*
d <s, h, k>			*a*b!		*	*
e <s, t, ʔ>		*a!*b			*	*

68 A ranking of: *[COR], *FRIC » ID[PL] » PREC(ID[CONT], ID[PL]), ID[CONT] » PREC(ID[PL], ID[CONT]).

69 This violation follows from the assumption that since /h/ has no place, adding place will not incur a violation of ID[PLACE], but losing place, as in /s/ → [h], does incur a violation.

Since two reasonable PRECEDENCE constraint rankings have failed thus far, we can use recursive constraint demotion in a comparative tableau to determine if a consistent ranking of these constraints exists. As illustrated in (18), *[COR] is never violated (indicated by Ws only) and is highly ranked in the first RCD pass. However, a second pass reveals that no constraint ranking will result in all Ls dominated by a W. Thus, a comparative tableau shows us that it is not possible to find a consistent ranking which can select both the transparent and opaque outputs forms with these PRECEDENCE constraints, even when the metaconstraint is violated.

(18) Comparative tableau indicating ranking inconsistencies

W~L	*[COR]	PREC (ID[CONT], ID[PL])	PREC (ID[PL], ID[CONT])	*FRIC	ID [PLACE]	ID [CONT]
<h, k>~<h>	(0~0)	L (1~0)	(0~0)	W (0~1)	(0~0)	L (1~0)
<s, h>~<s>	W (0~1)	(0~0)	L (1~0)	(1~1)	L (1~0)	(0~0)
<s, h>~<s, t>	W (0~1)	W (0~1)	L (1~0)	L (1~0)	L (1~0)	W (0~1)
<s, h>~<s, h, k>	(0~0)	(0~0)	W (1~2)	L (1~0)	(1~1)	W (0~1)
<s, h>~<s, t, ʔ>	(0~0)	W (0~2)	L (1~0)	L (1~0)	(1~1)	W (0~1)

3.3.2. Modified /s/-based L1 representations

The ranking paradox in (18) indicates that we need to split the (a) and (b) clauses into individually ranked constraints. The split PRECEDENCE constraints for PREC(ID[PLACE], ID[CONT]) and PREC(ID[CONT], ID[PLACE]) are given in (19) and (20).

(19) PREC(ID[PLACE], ID[CONT]) splits into:

(a) ID[PL]←ID[CONT]: ID[CONT] violation must be preceded by ID[PL] violation

(b) *ID[CONT]-THEN-ID[PL]: no ID[PL] violation after ID[CONT] violation

(20) PREC(ID[CONT], ID[PLACE]) splits into:

(a) ID[CONT]←ID[PL]: ID[PL] violation must be preceded by ID[CONT] violation

(b) *ID[PL]-THEN-ID[CONT]: no ID[CONT] violation after ID[PL] violation

We can replace the PRECEDENCE constraints with the individual clause constraints and again use RCD in a comparative tableau to determine if a consistent ranking is possible with this revised set of constraints, as illustrated in (21).

(21) Comparative tableau with successful split PRECEDENCE ranking

W~L	*[COR]	*ID[P] -THEN- ID[C]	*ID[C] -THEN- ID[P]	*FRIC	ID[P]	ID[C]	ID[C] ← ID[P]	ID[P] ← ID[C]
<h, k>~ <h>	(0~0)	(0~0)	(0~0)	W (0~1)	(0~0)	L (1~0)	L (1~0)	(0~0)
<s, h>~ <s>	W (0~1)	(0~0)	(0~0)	(1~1)	L (1~0)	(0~0)	L (1~0)	(0~0)
<s, h>~ <s, t>	W (0~1)	(0~0)	(0~0)	L (1~0)	L (1~0)	W (0~1)	L (1~0)	W (0~1)
<s, h>~ <s, h, k>	(0~0)	W (0~1)	(0~0)	L (1~0)	(1~1)	W (0~1)	L (1~0)	(0~0)
<s, h>~ <s, t, ʔ>	(0~0)	(0~0)	W (0~1)	L (1~0)	(1~1)	W (0~1)	(1~1)	W (0~1)

In (21), *[COR], *ID[P]-THEN-ID[C] and *ID[C]-THEN-ID[P] are not violated and can receive an undominated ranking on the first pass. This leaves only a single candidate pair row, <h, k>~<h>, in need of a W. This W comes from ranking *FRIC in the next pass and now all unattested forms can be eliminated with this constraint ranking. The remaining constraints do not affect selection of the optimal candidate and they can remain relatively unranked. We can see that the success of this ranking indicates that this child's grammar requires the same OT-CC modifications required by the early child chain shift opacity scenarios in chapter 2. The successful ranking in (21) can also be represented with a violation tableau, as shown in (22).

(22) Violation tableau with successful split PRECEDENCE ranking

/h/	*[COR]	*ID[P] -THEN- ID[C]	*ID[C] -THEN- ID[P]	*FRIC	ID[P]	ID[C]	ID[C] ← ID[P]	ID[P] ← ID[C]
a <h>				*!				
b ☞<h, k>						*	*a	
/s/								
a <s>	*!			*				
b ☞<s, h>				*	*		*a	
c <s, t>	*!					*		*a
d <s, h, k>		*b!			*	*		
e <s, t, ʔ>			*b!		*	*	*a	*a

At this point, we can see that the contrast between early child and adult opacity patterns extends across /s/-based chain shifts in child and adult L2 grammars. We can also see a clearer contrast in the nature of the processes that are available in these developing grammars. Adult L2 processes appear to be driven by cross-linguistic markedness and L1 influence (i.e., transfer). Although the child processes are general ones in many respects, they are not motivated by the target grammar, nor do they always correspond to cross-linguistic patterns of markedness. The source of the respective chain shift processes appears to be very different for adults and children, particularly in terms of access to a previously developed grammar. This effects not only the types of processes available in a grammar, but also the contexts in which they apply. In lieu of another prominent influence, processes in early child grammar appear to be largely driven by the initial state. However, extended language exposure appears to cause developing L1 grammars to acquire more adult-like aspects long before reaching a final-state, as seen in the types of processes, and process interactions, exhibited by children with phonological delays.

3.4. Opacity in phonological delayed grammars

Researchers in the Learnability Project at Indiana University particularly focus on children with phonological delays, but who are otherwise typically developing.[70] The phonologies of children with delays are assumed to pass through the same stages of acquisition as the phonologies of typically developing children, merely over a longer period of time (Dinnsen and Barlow 1998; Dinnsen *et al*. 2000; Dinnsen and Gierut 2008; Dinnsen *et al*. 2011). Thus, these researchers suggest that

[70] For a comprehensive overview of the delayed development research conducted by the Learnability Project at Indiana University, go to http://www.indiana.edu/~sndlrng/reports.htm.

data from phonologically delayed children can offer insight into early phonological development stages while avoiding the challenges involved with working with young children when gathering the type and amount of data needed to motivate phonological claims. In this section I present OT-CC analyses of the opaque productions from two of these studies. Dinnsen, McGarrity, O'Connor and Swanson (2000) look at opaque interactions between vowel lengthening and final coda deletion in 3 children aged 7;2 (Child A), 7;6 (Child B) and 3;10 (Child C). Dinnsen, Green, Gierut and Morrisette (2011) look at interactions between labialization and dentalization in a cross-sectional study of 234 children ranging from 3;0 to 7;9. The children in each of these studies were considered to be typically developing in all respects except for evidence of a phonological delay.

3.4.1. Phonologically delayed over-application

Phonologically delayed L1 counterbleeding data comes from the Dinnsen *et al*. (2000) child acquisition study which reveals an interaction between the processes of vowel lengthening before voiced consonants and final consonant deletion. Vowel lengthening is a target process for English, but coda deletion is typically considered non-target, or at least only marginally target for some dialects of English.[71] Since final consonants can form part of the conditioning environment for lengthening, there is significant potential for these phenomena to co-occur, which appears to

[71] Deletion of coronal stops in complex coda clusters does occur in some casual native English speech. If it is part of the input it cannot be completely categorized as a non-target process.

stipulate some type of process application order. The source of the data for Dinnsen *et al*. (2000) is an instrumental study of three phonologically delayed children by Weismer, Dinnsen, and Elbert (1981). All three children omit final obstruents, but only two of them (child A and child B) maintained a statistically significant vowel length distinction. For these two children, vowels were long before (underlying) voiced obstruents (e.g., /kæb/ → [kæː]) and short elsewhere (e.g., /pæt/ → [pæ]). Lengthening without an overt triggering environment creates an instance of over-application phonological opacity, as illustrated in the tokens in (23).

(23) Productions for child A (age 7;2)

a. Voiced coda triggered lengthening and deletion

[kæː]	‘cab’	[ka]	‘cop’
[kɪː]	‘kid’	[pæ]	‘pat’
[dɔː]	‘dog’	[dʌ]	‘duck’

b. No coda (CV.CV) = no lengthening or deletion

[kæbi]	‘cabby’	[kapoʊ]	‘copper’
[kidoʊ]	‘kidder’	[pæti]	‘patty’
[dɔgi]	‘doggie’	[dʌki]	‘ducky’

In contrast to Child A’s productions, Child C exhibited no environmentally conditioned vowel lengthening, regardless of the voicing of the deleted coda. An input like /it/ ‘*eat*’ was produced as [i] and an input like /dɔg/ ‘*dog*’ was produced as [dɔ] rather than [dɔː], resulting in phonologically transparent productions.

The MARKEDNESS constraints in (24)(a-b) and the FAITHFULNESS constraints in (24)(c-d) are based on Dinnsen *et al*. (2000), who suggest them as part of a Sympathy analysis of the opacity scenario for Child A, but have been reformulated to conform to McCarthy's (2007, 2008) *violation assignment* definitions.

(24) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. LENGTHEN: assign one violation mark for every short vowel before a voiced coda consonant; assign one violation mark for every long vowel elsewhere

b. *CODA: assign one violation mark for every obstruent in coda position

c. ID[LENGTH]: assign one violation mark for every set of corresponding input-output segments which have different values for [LENGTH]

d. MAX: assign one violation mark for every input segment which does not have a corresponding segment in the output

Vowel lengthening (i.e., /kæb/ → [kæːb]) is motivated by a ranking of LENGTHEN » ID[LENGTH], where ID[LENGTH] is violated to satisfy LENGTHEN. Coda deletion (i.e., [kæːb] → [kæː]), is motivated by a ranking of *CODA » MAX, where MAX is violated to satisfy *CODA. In general, MARKEDNESS constraints are not violated, so Dinnsen *et al*. consolidate the relative rankings in the MARKEDNESS » FAITHFULNESS ranking in (25).

(25) *CODA, LENGTHEN » MAX, ID[LENGTH]

Based on this ranking, Harmonic Serialism generates the set of candidate chains in (26). When the input contains a voiceless coda, as in (26)a, coda deletion is the only harmonic change. But when the input contains a voiced coda, as in (26)b, more than one harmonically improving change, or sequence of changes, is possible. Vowel lengthening is of course not a harmonic change in the environment of either a voiceless coda or no coda and violation orderings involving ID[LENGTH] should not be possible when LENGTHEN is not triggered. Thus, candidate chains such as <kæb, kæ, kæː> (or <pæt, pæːt, pæː>), which have non-harmonic vowel lengthening (i.e., not motivated by coda voicing), are eliminated from the set of possible candidates.[72]

(26) Candidate chains for vowel lengthening and coda deletion:

a. chains for input /pæt/		b. chains for input /kæb/	
<pæt>	*no change*	<kæb>	*no change*
<pæt, pæ> ✓	*delete coda*	<kæb, kæːb>	*lengthen*
		<kæb, kæ>	*delete coda*
		<kæb, kæːb, kæː> ✓	*lengthen*; *del coda*

These candidates can be preliminarily evaluated in the tableau in (27), but no permutation of the relative rankings in (25) will select both correct outputs.

[72] This follows from only incremental harmonically improving changes forming a candidate chain. Under Harmonic Serialism, introduced in chapter 1, non-harmonic changes are eliminated as possible stages within candidate chains even when the final output is the attested one.

(27) Standard OT selecting correct transparent, incorrect opaque candidate

/pæt/ 'pat'	*CODA	LENGTHEN	MAX	ID[LENGTH]
a <pæt>	*!			
b ☞<pæt, pæ>			*	
/kæb/ 'cab'				
a <kæb>	*!	*		
b <kæb, kæːb>	*!			*
c ☜<kæb, kæ>			*	
d →<kæb, kæːb, kæː>		*!	*	*

Thus, it is necessary to evaluate the internal stages of the candidate chains. The PRECEDENCE constraints for MAX and ID[LENGTH] are given in (28), and have the corresponding metaconstraints of MAX » PREC(ID[LENGTH], MAX) and ID[LENGTH] » PREC(MAX, ID[LENGTH]). However, when these are obeyed the PRECEDENCE constraints are ranked too low to change the output selections, as shown in (29).

(28) *PREC(ID[LENGTH], MAX)*: assign a violation mark whenever

(a) a violation of MAX occurs and is not preceded by a violation of ID[LEN], or

(b) a violation of MAX occurs and is followed by a violation of ID[LEN]

PREC(MAX, ID[LENGTH]): assign a violation mark whenever

(a) a violation of ID[LEN] occurs and is not preceded by a violation of MAX, or

(b) a violation of ID[LEN] occurs and is followed by a violation of MAX

(29) Standard OT-CC (metaconstraint) ranking: failed opaque selection

/pæt/ 'pat'	*Coda	Leng-then	Max	Prec (Id[L], Max)	Id [len]	Prec (Max, Id[L])
a <pæt>	*!					
b ☞<pæt, pæ>			*	*a		
/kæb/ 'cab'						
a <kæb>	*!	*				
b <kæb, kæːb>	*!				*	*a
c ☜<kæb, kæ>			*	*a		
d →<kæb, kæːb, kæː>		*!	*		*	*a*b

Based on the ranking in (25), the opaque output would be selected only if the metaconstraint were violated, as in (30). Dinnsen *et al*. (2000) do not supply explicit reasons for the ranking in (25), but if there are independent reasons for this specific ranking, then phonologically delayed over-application, like the over-application opacity in chapter 2, would require violating the metaconstraint, as shown in (30).

(30) OT-CC with violated metaconstraint: successful opaque output selection

/pæt/ 'pat'	*Coda	Prec (Id[L], Max)	Leng-then	Max	Id [len]	Prec (Max, Id[L])
a <pæt>	*!					
b ☞<pæt, pæ>		*a		*		
/kæb/ 'cab'						
a <kæb>	*!		*			
b <kæb, kæːb>	*!				*	*a
c <kæb, kæ>		*a		*		
d ☞<kæb, kæːb, kæː>			*!	*	*	*a*b

However, without explicit justification for Dinnsen *et al.*'s original ranking, we can use a comparative tableau to determine if a violated metaconstraint ranking is the only possible consistent OT-CC ranking. As shown in (31), *Coda has only Ws and receives a high ranking on the first RCD pass. It appears that Prec(Id[len], Max) should receive the next high ranking slot since it contains a crucial W. Max does not have any Ws to suggest it should receive a high ranking, but since *Coda is satisfied through violating Max, it is only necessary for Max to be dominated by *Coda. Ranking Max below *Coda and above Prec(Id[len], Max) does not create a problematic ranking with an L undominated by a W. For this counterbleeding scenario, the only remaining crucial domination is Prec(Id[len], Max) » Lengthen. This gives us a consistent ranking which eliminates all ungrammatical outputs.

(31) Comparative tableau with consistent ranking (after RCD)

W~L	*Coda	Max	Prec (Id[l], Max)	Leng-then	Id [len]	Prec (Max, Id[l])
<pæt, pæ> ~<pæt>	W (0~1)	L (1~0)	L (1~0)	(0~0)	(0~0)	(0~0)
<kæb, kæ:b, kæ:> ~<kæb>	W (0~1)	L (1~0)	(0~0)	(1~1)	L (1~0)	L (2~0)
<kæb, kæ:b, kæ:> ~<kæb, kæ:b>	W (0~1)	L (1~0)	(0~0)	L (1~0)	(1~1)	L (2~1)
<kæb, kæ:b, kæ:> ~<kæb, kæ>	(0~0)	(1~1)	W (0~1)	L (1~0)	L (1~0)	L (2~0)

The alternative ranking for these MARKEDNESS and FAITHFULNESS constraints, where MAX is initially ranked above LENGTHEN, selects both the transparent and the opaque outputs without violating the metaconstraints. This successful ranking can also be represented in a violation tableau format, as shown in (32).

(32) Successful violation tableau with standard OT-CC

/pæt/ 'pat'	*CODA	MAX	PREC (ID[L], MAX)	LENG-THEN	ID [LEN]	PREC (MAX, ID[L])
a <pæt>	*!					
b ☞<pæt, pæ>		*	*a			
/kæb/ 'cab'						
a <kæb>	*!			*		
b <kæb, kæːb>	*!				*	*a
c <kæb, kæ>		*	*a!			
d ☞<kæb, kæːb, kæː>		*		*	*	*a*b

The constraint ranking for this child counterbleeding opacity can be compared to a possible ranking for the non-opaque adult output, shown in (33). The only significant difference between the child and adult constraint rankings involves promoting the FAITHFULNESS constraint MAX over *CODA.[73] This reranking essentially reverses only the domination relationship of this MARKEDNESS and FAITHFULNESS pair

[73] Since PREC(ID[LEN], MAX) assigns the same violation set as MAX here, this constraint can be ranked directly below MAX, or stay in its position from the child grammar in (32), without affecting output selection. Furthermore, while a constraint like *CODA is assumed to have a low ranking in English, merely ranking MAX over *CODA in this grammar is sufficient to select the correct output and there is insufficient evidence of a relative ranking between *CODA and the remaining constraints.

from the child grammar that motivates the non-target process of coda deletion. The remainder of the child grammar already appears to have an adult-like ranking.

(33) Non-opaque adult grammar with standard OT-CC representation

/pæt/ 'pat'	MAX	*CODA	PREC (ID[L], MAX)	LENG-THEN	ID [LEN]	PREC (MAX, ID[L])
a ☞<pæt>		*				
b <pæt, pæ>	*!		*a			
/kæb/ 'cab'						
a <kæb>		*		*!		
b ☞<kæb, kæːb>		*			*	*a
c <kæb, kæ>	*!		*a			
d <kæb, kæːb, kæː>	*!			*	*	*a*b

As seen in chapter 1, counterbleeding opacity in an adult grammar would result in at least a partial raking of FAITHFULNESS » PRECEDENCE in order to allow the metaconstraint, which forces PRECEDENCE constraints to be ranked below their B FAITHFULNESS constraint. Similarly, the ranking for the non-opaque adult grammar is also expected to have a general ranking of FAITHFULNESS » PRECEDENCE to allow metaconstraints, regardless of the lack of activity for PRECEDENCE constraints in non-opaque scenarios. The child ranking in (32) and the adult ranking in (33) both appear to follow a general ranking of FAITHFULNESS » PRECEDENCE. This suggests that this child's grammar, in spite of producing at least partially non-target opacity, still exhibits an adult-like constraint ranking in regard to the availability of the metaconstraints. This is also the case for Child C's grammar, where the PRECEDENCE constraints not only must be ranked below key MARKEDNESS constraints, e.g., *CODA and LENGTHEN, but require the metaconstraint of ID[MAX] » PREC(ID[LEN], MAX) to avoid an opaque interaction.

(34) Standard OT-CC analysis of Child C's grammar

/it/ 'eat'	*CODA	MAX	LENGTHEN	PREC (ID[L], MAX)	ID [LEN]	PREC (MAX, ID[L])
a <it>	*!					
b ☞<it, i>		*		*a		
/dɔg/ 'dog'						
a <dɔg>	*!		*			
b <dɔg, dɔːg>	*!				*	*a
c ☞<dɔg, dɔ>		*		*a		
d <dɔg, dɔːg, dɔː>		*	*!		*	*a*b

The availability of the metaconstraint in the grammar of both the opaque and non-opaque phonologically delayed child from Dinnsen *et al*. (2000) contrasts with the early Korean L1 learner (Cho and Lee 2003), as well as Amahl (Smith 1973) and Joan (Velten 1943) from chapter 2, since the metaconstraint must be violated in these early grammars.

3.4.2. Phonologically delayed chain shifts

Phonologically delayed L1 under-application data comes from a child acquisition study by Dinnsen *et al*. (2011). They look at the interaction of the processes of labialization, where /θ/ → [f] and '*thumb*' is realized as [fʌm], and dentalization, where /s/ → [θ] and '*some*' is realized as [θʌm], in children with delayed phonological development. While labialization may be considered a partially target process since it occurs in some dialects of English, dentalization is a non-target process for English.[74] These processes have the potential to interact in a feeding chain shift of *s>θ>f*, but the full shift is unattested and interdentals derived from the process of dentalization do not undergo labialization.[75] Of the 160 children, all with functional phonological delays, whose grammars contain both processes, eleven children (mean age of 4;1) exhibited the co-occurrence of labialization and dentalization in a what appears to be a standard counterfeeding interaction. The data in (35) comes from a single child, but is representative of all the children in this study whose grammars exhibit both processes.

(35) Child 131 (age 4;8): counterfeeding chain shift

a. /s/ replaced by [θ] (dentalization)

[bʌθ]	'bus'	[maʊθ]	'mouse'
[aɪθi]	'icy '	[beɪθbɔ]	'baseball'

b. /θ/ replaced by [f] (labialization)

[maʊf]	'mouth'	[fʌndʊ]	'thunder'
[fʌm]	'thumb'	[tuf]	'tooth'

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74 In fact, this substitution pattern is the opposite for cross-linguistic substitution patterns of /θ/ in child acquisition, where /s/ or /t/ are the most common substitutions for /θ/.

75 These children do not even show the predicted grandfather effect of a full chain shift for derived environments, where /s/ → [θ] → [f] for input /s/, but /θ/ → [θ] when that is the input.

c. /f/ produced target-appropriately

[kɔf]	'cough'	[wæfin]	'laughing'
[faɪy̥]	'five'	[faɪjʊ]	'fire'

The logically possible sequential process orderings are illustrated in (36) and (37). If dentalization happens first, it will feed labialization, producing the unattested feeding pattern in (36). If labialization happens first, then labialization will fail to feed dentalization, producing the attested counterfeeding pattern in (37).

(36) Dentalization first:	/sʌm/ 'some'	/θʌm/ 'thumb'	/fʌn/ 'fun'
dentalization	[θʌm]	*n/a*	*n/a*
labialization	[fʌm]	[fʌm]	*n/a*

(37) Labialization first:	/sʌm/ 'some'	/θʌm/ 'thumb'	/fʌn/ 'fun'
labialization	*n/a*	[fʌm]	*n/a*
dentalization	[θʌm]	*n/a*	*n/a*

Unlike the child under-application opacity in chapter 2 and §3.3, the sequential ordering in (37) does form a *counterfactual inverse* (Baković 2011) of the ordering in (36), and this provides and early indication that this interaction is true counterfeeding. We can also see that the counterfeeding order in (37) produces the same output forms as simultaneous application, shown in (38).

(38) Simultaneous rule application:

a. /sʌm/ → [θʌm] (UR meets structural description for dentalization)

b. /θʌm/ → [fʌm] (UR meets structural description for labialization)

The MARKEDNESS constraints in (39)(a-b) and the FAITHFULNESS constraints in (39)(c-e) are based on those in Dinnsen *et al.*'s (2011) analysis.[76] *[DENT] restricts segments with a dental feature and motivates the process of labialization. Dinnsen *et al*. follow Ladefoged and Maddieson (1996) in describing /s/ → [θ] as a process involving a manner change from a grooved[77] to a non-grooved fricative. *[GRVD] restricts grooved, or strident features and motivates the process of dentalization.

(39) Relevant MARKEDNESS and FAITHFULNESS constraints:

a. *[DENT]: assign one violation mark for every segment with the feature [DENT]

b. *[GRVD]: assign one violation mark for every segment with the feature [GRVD]

c. ID[GRVD]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [GRVD]

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[76] These MARKEDNESS constraints are slightly revised from the single segment forms of *θ and *s in Dinnsen *et al*. (2011). The constraint forms here capture essentially the same restrictions, but represent broader scope application of feature changes.

[77] Grooved sounds are sometimes equated with the feature [+STRIDENT] (e.g. Chomsky & Halle 1968).

d. ID[COR]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [COR][78]

e. ID[CONT]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [CONT]

Stopping is ungrammatical in this child's grammar and this is reflected in an undominated ranking of the FAITHFULNESS constraint ID[CONT].[79] Dentalization of grooved coronal fricatives (i.e., /sʌm/ → [θʌm]) is motivated by a ranking of *[GRVD] » ID[GRVD], where ID[GRVD] is violated to satisfy *[GRVD]. Labialization of interdental fricatives (i.e., /θʌm/ → [fʌm]), is motivated by a ranking of *[DENT] » ID[COR], where ID[COR] is violated to satisfy *[DENT]. These relative rankings can be combined in an overall ranking, consistent with these changes, given in (40).

(40) ID[CONT] is unviolated; *[GRVD] » ID[GRVD]; *[DENT] » ID[COR]

Note that the phonologically delayed process of replacing /s/ with /θ/ is a *reverse* of what happens with adult L2 learners, who replace /θ/ with /s/ in interlanguage

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[78] Dinnsen *et al*. (2011) describe the change of /θ/ to [f] as a change in the [CORONAL] place feature.

[79] This undominated ranking means that ID[CONT] is never violated in the grammars that allow fricatives, as seen in (42). As such, it does not significantly contribute to the violation assignments and can be excluded from the tableaux for these grammars. However, it is again necessary in later discussion of alternative resolutions for coronal fricatives where it receives a lower ranking.

grammars.[80] Neither the adults nor the children violate ID[CONT]; however, violating *[DENT] in the child grammars is more optimal due to a higher ranking of *[GRVD]. This constraint has presumably moved below *[DENT] in the adult grammars.

Based on the ranking in (40), Harmonic Serialism generates the set of candidate chains for the inputs /maʊθ/ and /maʊs/ given in (41). When the input contains an interdental fricative, labialization of the fricative is the only harmonically improving change, as shown in (41)a. However, when the input contains a grooved fricative, a succession of harmonically improving changes is possible, as shown in (41)b.

(41) Candidate chains for labialization and dentalization:

a. <u>chains for input /maʊθ/</u>		b. <u>chains for input /maʊs/</u>	
<maʊθ>	no change	<maʊs>	no change
<maʊθ, maʊf> ✓	labialize	<maʊs, maʊθ> ✓	dentalize
		<maʊs, maʊθ, maʊf>	dentalize, labialize

The constraint rankings in (40) select the correct transparent output but fail to select the correct opaque output, as in (42).

[80] While the adult pattern appears to be marked > unmarked, the child patterns do not always seem to follow this pattern. In fact, the phonologically delayed child pattern appears to be unmarked > marked. However, this may be a consequence of some aspect of the phonological delay.

(42) Standard OT failure in selecting correct opaque candidate

/maʊθ/	ID[CONT]	*[GRVD]	ID[GRVD]	*[DENT]	ID[COR]
a <maʊθ>				*!	
b ☞<maʊθ, maʊf>					*
/maʊs/					
a <maʊs>		*!			
b →<maʊs, maʊθ>			*	*!	
c ☜<maʊs, maʊθ, maʊf>			*		*

This standard OT failure indicates it is necessary to evaluate the internal stages of the candidate chains. The PRECEDENCE constraints for ID[GRVD] and ID[COR] are given in (43), and have the corresponding metaconstraints of ID[GRVD] » PREC(ID[COR], ID[GRVD]) and ID[COR] » PREC(ID[GRVD], ID[COR]).

(43) *PREC(ID[COR], ID[GRVD])*: assign a violation mark whenever

(a) a violation of ID[GRD] occurs and is not preceded by a violation of ID[COR], or

(b) a violation of ID[GRD] occurs and is followed by a violation of ID[COR]

PREC(ID[GRVD], ID[COR]): assign a violation mark whenever

(a) a violation of ID[COR] occurs and is not preceded by a violation of ID[GRD], or

(b) a violation of ID[COR] occurs and is followed by a violation of ID[GRD]

The comparative tableau in (44) quickly captures the crucial constraint rankings and confirms that a consistent ranking exists where every L is dominated by a W.

(44) Comparative tableau showing crucial constraint rankings

W~L	*[GRVD]	ID [GRVD]	PREC (ID[COR], ID[GRVD])	*[DENT]	ID [COR]	PREC (ID[GRVD], ID[COR])
<maʊθ, maʊf>~ <maʊθ>	(0~0)	(0~0)	(0~0)	W (0~1)	L (1~0)	L (1~0)
<maʊs, maʊθ>~ <maʊs>	W (0~1)	L (1~0)	L (1~0)	L (1~0)	(0~0)	(0~0)
<maʊs, maʊθ>~ <maʊs, maʊθ, maʊf>	(0~0)	(1~1)	W (1~2)	L (1~0)	W (0~1)	(0~0)

Importantly, the opaque candidate can be selected while obeying the metaconstraints. This contrasts with the early typical development chain shifts seen in Amahl and Joan in chapter 2 and Child. S.H. in §3.3, where not only were the metaconstraints violated, but the PRECEDENCE constraints were also be split into individual clause constraints. The successful ranking for the comparative tableau in (44) is recreated in the violation tableau in (45).

(45) Successful standard OT-CC analysis

/maʊθ/	*[GRVD]	ID [GRVD]	PREC (ID[COR], ID[GRVD])	*[DENT]	ID [COR]	PREC (ID[GRVD], ID[COR])
a <maʊθ>				*!		
b ☞<maʊθ, maʊf>					*	*a
/maʊs/						
a <maʊs>	*!					
b ☞<maʊs, maʊθ>		*	*a	*		
c <maʊs, maʊθ, maʊf>		*	*a*b!		*	

Interestingly, the tableau in (44) and (45) do not require a strict ranking between the FAITHFULNESS constraint ID[GRVD] and the PRECEDENCE constraint PREC(ID[COR], ID[GRVD]). However, this is similar to standard OT-CC analyses of adult counterfeeding where the metaconstraint is obeyed when it is not strictly necessary to violate it. But importantly, in this delayed counterfeeding opacity there is no requirement for splitting the PRECEDENCE constraints into individual clause constraints as there was in the cases of early typical phonological development in chapter 2 and §3.3.

3.4.3. Alternative repair implications for OT-CC

One relevant observation by Dinnsen *et al*. is in regard to the lack of evidence in their data for any type of feeding interaction between labialization and dentalization. They ultimately attribute this to OT-CC having a built-in mechanism for disallowing particular feeding interactions and show that if PREC(ID[COR], ID[GRVD]) is ranked above the MARKEDNESS constraint banning interdental fricatives, *[DENT], but below the MARKEDNESS constraint banning grooved coronal fricatives, *[GRVD], it will eliminate the feeding candidate <maʊs, maʊθ, maʊf> in favor of the counterfeeding candidate <maʊs, maʊθ>. This is precisely the ranking in (45).

However, Dinnsen *et al*. also observe that as it is currently conceived, OT-CC should also erroneously predict a feeding interaction if the hierarchy were essentially the same in all respects, except that the two MARKEDNESS constraints against coronal fricatives (i.e., *[GRVD] and *[DENT]) were ranked above

PREC(ID[COR], ID[GRVD]). In order to satisfy these two MARKEDNESS constraints, while still complying with ID[CONT], violations of ID[COR] would simply be overridden in such a scenario and all fricatives would be realized as [f], as shown in (46).[81] Dinnsen *et al*. further note that such a ranking might follow from the default ranking of MARKEDNESS over FAITHFULNESS in early stages of acquisition (Smolensky 1996).

(46) Feeding interaction resulting from undominated MARKEDNESS

/maʊθ/	*[GRVD]	*[DENT]	ID [CONT]	ID [GRVD]	PREC (ID[COR], ID[GRVD])	ID [COR]
a <maʊθ>		*!				
b ☞<maʊθ, maʊf>						*
/maʊs/						
a <maʊs>	*!					
b →<maʊs, maʊθ>		*!		*	*a	
c ☜<maʊs, maʊθ, maʊf>				*	*a*b	*

In order to avoid this unintended prediction, Dinnsen *et al*. suggest a modification to OT-CC for an initial-state, i.e., default, fixed ranking of ID[CONT] below PREC(ID[COR], ID[GRVD]). This fixed ranking would preclude a feeding interaction when the MARKEDNESS constraints against coronal fricatives are undominated by allowing alternative repair strategies. A fixed ranking of PREC(ID[COR], ID[GRVD]) » ID[CONT] allows stopping, the most common repair for illicit coronal fricative segments in children who do not show interaction of labialization and dentalization.

[81] This is not a factor at earlier stages of acquisition where ID[CONT] is violated in order to avoid fricatives, e.g., a ranking such as *FRIC » ID[CONT].

The productions in (47) come from Child 11 (age 4;11) who employs stopping to repair illicit coronal fricatives. This grammar utilizes a crucial violation of low ranking ID[COR] rather than employing the place altering processes of labialization or dentalization, even though the constraints *[GRVD] and *[DENT] are still a part of the inventory and could also be used to eliminate these segments.[82]

(47) OT-CC with alternative repair of coronal fricative (stopping)

/bʌs/	*[GRVD]	*[DENT]	ID [GRVD]	PREC (ID[COR], ID[GRVD])	ID [COR]	ID [CONT]
a <bʌs>	*!					
b ☞<bʌs, bʌt>			*	*a		*
c <bʌs, bʌf>			*	*a	*!	
/bæθ/						
a <bæθ>		*!				
b ☞<bæθ, bæt>						*
c <bæθ, bæf>					*!	

While the specific constraint ranking proposed by Dinnsen *et al*. provides a somewhat stipulative solution to potential feeding interactions, a wider-scope application of their suggestions could contain important theoretical implications. PRECEDENCE constraints, as proposed by McCarthy, are indeed a type of faithfulness; however, they are also a distinct class of constraints and considered separate from

[82] Fricatives are not allowed in this child's grammar and this could be shown in a straightforward manner by an undominated ranking of the general constraint against fricatives, *FRIC. However, since *[GRVD] and *[DENT] are also constraints against coronal fricatives, they can be used to represent the restriction against fricatives here for a more direct comparison of the rankings in (46) and (47).

the general classes of MARKEDNESS and FAITHFULNESS. Therefore, there are two initial state rankings of interest in child grammars. The first is the general ranking of MARKEDNESS and PRECEDENCE constraints. Dinnsen *et al.*'s ranking of *[GRVD], *[DENT] » PREC(ID[COR], ID[GRVD]) forms a ranking of MARKEDNESS » PRECEDENCE. The other ranking of interest is a general ranking of FAITHFULNESS and PRECEDENCE. The specific ranking of PREC(ID[COR], ID[GRVD]) » ID[CONT] suggested by Dinnsen *et al.* results in a ranking of PRECEDENCE » FAITHFULNESS. Consequently, an initial state ranking of MARKEDNESS » PRECEDENCE » FAITHFULNESS would restrict the unattested feeding pattern in these children's grammars without requiring a stipulated fixed ranking such as PREC(ID[COR], ID[GRVD]) » ID[CONT] since this ranking would occur by default in the initial state. And finally, since PREC(ID[COR], ID[GRVD]) and its B-FAITHFULNESS constraint ID[GRVD] assign identical sets of violations when the optimal coronal fricative repair is stopping rather maintaining continuance through feature change, there is no evidence for or against the metaconstraint of ID[GRVD] » PREC(ID[COR], ID[GRVD]). Again, this is similar to counterfeeding opacity in adult grammars since the metaconstraint ranking, based on partial FAITHFULNESS » PRECEDENCE, is available at this point in the child's grammar.

3.5. Conclusion

In this chapter, I have compared data from adult L2 acquisition, phonologically delayed child L1 acquisition, and typically developing child L1 acquisition. Opacity patterns in both L2 and delayed acquisition were shown to pattern like final-state

L1 adult opacity; both can be accounted for under standard OT-CC. By contrast, the non-ordered counterfeeding found in the Korean early child acquisition scenario, as well as the same type of opacity discussed in chapter 2, required meaningful modifications to OT-CC. Consequently, non-ordered opacity does *not* appear to be a by-product of general acquisition (learning). We can get a better sense of what drives this opacity pattern by examining the progression of treatment for opacity over the acquisition scenarios in this chapter and previous chapters.

The progression of occurrence and necessary OT-CC representations for the early typical development child L1, phonologically delayed child L1, adult L1 and adult L2 opacity patterns discussed in chapters 1 through 3 can be summarized in Table **3**. Under-application in these scenarios includes both counterfeeding and non-ordered counterfeeding, and over-application represents both counterbleeding and non-ordered counterbleeding. Differences in ordered versus non-ordered opacity are indicated by OT-CC treatment.

Table 3: Progression of opacity pattern occurrence and representation

	child NL (early >3;0)	child NL (delayed <3;0)	adult NL (stable)	adult L2 (IL)
under-application	✓	✓	✓	✓
over-application	✓	✓	✓	predict
PRECEDENCE	Split	joined	Joined	joined
metaconstraint	No	yes	Yes	yes

Although this table still contains gaps, the overall trend lends itself to specific predictions regarding them. Based on the natural progression seen in Table **3**, and especially the counterbleeding pattern in phonologically delayed children, adult L2 counterbleeding is predicted to both occur and obey the metaconstraint. However, it is also predicted to occur less frequently than adult L2 under-application opacity based on the typological frequency of these patterns in mature grammars. Table **3** suggests that the scope of non-ordered opacity appears to be restricted to language acquisition in children under the age of 3;0. In turn, this leads to a testable hypothesis that non-ordered opacity results from conditions on the initial state. These conditions are then transformed in the course of early development and cannot be recreated during later stages of acquisition.

We have seen in this chapter that at least the opacity emerging in adult L2 and early child L1 grammars can be distinguished on a few key points. One is that the metaconstraint ranking is available in the adult interlanguage grammars, similar to adult final-state L1 grammars. Another is that the phonological processes occurring within the adult interlanguage grammars, while non-target for the L2 grammar, are still viable processes in another grammar that are transferred from the L1. Thus, the processes occurring in adult acquisition are already defined by more incremental changes as opposed to the broad generalizations occurring in child acquisition. As such, differences between adult L2 acquisition opacity and child L1-acquisition opacity are not completely unexpected.

A more surprising result of this chapter is the apparent difference between early (ages of less than 3;0) and delayed (ages of greater than 3;0) child acquisition. Phonologically delayed productions are generally expected to emulate the acquisition stages of typical phonological development (Dinnsen *et al*. 2000; Dinnsen *et al*. 2011). Similar to the adult/child contrast, the most obvious difference between early and delayed acquisition production is the availability of the metaconstraint ranking in phonologically delayed grammars. Furthermore, unlike early acquisition processes, the processes in delayed child acquisition are a mixture of target and non/partially-target language processes. The counterbleeding opacity from Dinnsen *et al*. (2000) includes a target (vowel lengthening) and a marginally target (coda deletion) process while the counterfeeding opacity from Dinnsen *et al*. (2011) includes a non-target process (dentalization) and a dialectically limited process (labialization). These processes also differ from those occurring during early acquisition in terms of discrete changes. In particular, the processes for children with phonological delays exhibit more context specific incremental feature changes rather than the broader generalizations seen in early acquisition.

Although Table **3** appears to suggest that chronological age imposes some type of time limit on when non-ordered counterfeeding can emerge in a language, it is more likely that chronological age merely coincides with cumulative language exposure and the inevitable changes it triggers in early grammar structure. Changes to initial state structure are assumed to be a direct result of prolonged exposure to language input. Thus, they are likely to progress as part of general language acquisition regardless of phonological delays. The strongest correlation with chronological age may reside in the general cognitive development associated with age progression which may affect simultaneous versus sequential process application and the types of language generalizations.

The age-paralleling occurrence we have seen for non-ordered opacity in L1-acquisition allows us to make testable predictions regarding the occurrence of this type of opacity in later grammars. One such prediction is that this pattern should never emerge during adult L2-acquisition because interlanguages are already adult grammars. Additionally, since we saw a general move from non-ordered to ordered opacity occurring during L1-acquisition in this chapter, we can also predict that non-ordered opacity is unlikely to make it into a stable adult grammar. However, since Wolf (2011) claims that stable simultaneous application is at least theoretically possible, a pattern which shares certain defining features with the child non-ordered opacity patterns could occur in a mature grammar.

Thus far, we have seen that the availability of the metaconstraint ranking plays an important role in defining the type of opacity pattern that can emerge during language acquisition. However, in both chapter 2 and in this chapter, we saw that there are also key differences in the types of processes that apply (as well as *how* they apply). These are the differences that require a split PRECEDENCE representation for early child opacity. Phonological generalizations are largely driven by the format of the MARKEDNESS constraints available in the grammar as well as their relative rankings. I turn to a more in-depth discussion of the initial state in chapter 4, where I look at how differences between early child opacity and phonologically delayed opacity suggest that there are fundamental and irreversible changes occurring in the initial state that carry through all future grammar states.

CHAPTER 4:
THE SOURCE OF DEVELOPMENTAL OPACITY

4.1. Introduction

The child opacity scenarios analyzed in chapters 2 and 3 show that non-ordered opacity emerges across production in multiple children under the age of 3;0 as well as across multiple languages. Furthermore, a comparison of these early opaque productions to those found in children with phonological delays and adults acquiring a second language suggests that non-ordered opacity is strictly limited to early child developmental stages. While previous chapters focus on a representation of the data that reveals differences between ordered and non-ordered opacity, in this chapter, I outline the primary constraint-driven motivation behind non-ordered opacity. I argue that the default constraint structures of the initial state actually create the conditions for non-ordered opacity; this pattern is then prohibited during later stages by required, acquisition-related, constraint re-ranking. I also propose a constraint driven source and motivation for the broad generalizations made by children that stems from constraints in the initial state having the most stringent (i.e., most general) form. Since generalizations in OT directly result from MARKEDNESS and FAITHFULNESS conflicts, the most stringent constraint forms lead to the broadest possible generalizations during early acquisition.

The first part of chapter 4 focuses on interactions between constraint classes and is organized in the following way. In §4.2 I introduce previous proposals for the initial state under an OT framework and then show how it became necessary to expand upon the original default MARKEDNESS » FAITHFULNESS ranking to include an additional class of PRECEDENCE constraints introduced as part of an OT-CC analysis of opaque interactions. In §4.3 I examine three stages of child language development/acquisition by reanalyzing data from a diary study by Ettlinger (2009). Stage 1 is the initial state and has an OT-CC default ranking of MARKEDNESS » PRECEDENCE » FAITHFULNESS. Stage 2 shows how limited demotion of MARKEDNESS constraints creates the conditions for opaque interactions. Stage 3 shows the eventual dominance of FAITHFULNESS constraints, along with a resulting preference for more faithful and more transparent productions. In §4.4 I look at opacity as a natural developmental stage by comparing the constraint ranking stages of phonologically typical children to those with a phonological delay. I further predict that there is an inevitable stage of opaque production during language development, regardless of opacity pattern differences between typical and delayed children.

The second part of this chapter looks at how the constraints themselves are structured in the initial state and how this structure shapes early grammar generalizations. In §4.5 I outline a proposal of *Constraint Compression*, where the constraints in the initial state have the most stringent forms possible. These constraints are then exploded (split) into subconstraints defined by a subset of the violation assignments of the original constraint. Constraint explosions are motivated by positive evidence and occur gradually during acquisition. Thus, the constraint structure of-the-moment influences the types of generalizations children make. I specifically look at the impact that splitting MARKEDNESS and FAITHFULNESS constraints have on general grammar markedness. A MARKEDNESS constraint explosion is illustrated by a MANNER based hierarchy for *CODA and a FAITHFULNESS constraint explosion is illustrated by the influence separate forms of IDENT[MANNER] have on L2 substitution patterns in a study by Lombardi (2003). These changes to the underlying grammar are similar in nature to those which splitting PRECEDENCE constraints had on accounting for the non-ordered opacity emerging in the developing grammars in chapters 2 and 3. A corresponding impact occurs to the incremental and harmonic changes that are initially based on stringent constraint forms favoring the least marked outputs. In §4.6 I conclude with an overview of the developmental transformations, i.e., re-ranking between classes and constraint explosions, that act on the initial state, and the permanent nature of such changes.

4.2. The structure of the initial state

As briefly discussed in chapter 1, the supposition of an initial state ranking of MARKEDNESS » FAITHFULNESS in OT stems from general principles of language *learnability*. Research in first language acquisition within an OT framework (Demuth 1995; Gnandesikan 1995, 2004; Pater 1997; Smolensky 1996; Tesar and Smolensky 1998; Jusczyk, Smolensky and Allocco 2002, among others) claims that certain classes of constraints must be biased toward higher ranking in order to ultimately result in sufficiently restrictive final-state grammars.[83] With an initial state of MARKEDNESS » FAITHFULNESS, language input is first modified to conform to a grammar that prefers less marked structures since FAITHFULNESS constraints are freely violated in favor of satisfying higher ranked MARKEDNESS constraints, i.e., *CODA » MAX produces a CV output from CVC input. Such an initial state corresponds to evidence from first language acquisition where a child's early productions consist primarily of unmarked forms (Gnandesikan 1995). But ultimately, the conflict between language input and non-target outputs will prompt demotion of the MARKEDNESS constraints that are violable in the target language below their conflicting FAITHFULNESS counterparts. Language learnability is therefore essentially the ability to re-rank constraints until the constraint ranking matches that of the target language (Tesar and Smolensky 1998).

Mature grammars thus converge on a closer correspondence between input and output and this reflects a general re-ranking toward FAITHFULNESS » MARKEDNESS. Not all MARKEDNESS constraints will be demoted and particular generalizations will still be expressed by specific MARKEDNESS » FAITHFULNESS rankings.[84] In contrast to such language specific re-ranking, if the initial state ranking was FAITHFULNESS » MARKEDNESS, then input forms would be produced faithfully, regardless of specific markedness restrictions. Language input would be matched in the output forms, but

[83] An initial ranking of MARKEDNESS » FAITHFULNESS would allow an eventual target-language re-ranking of FAITHFULNESS over MARKEDNESS based on limited positive evidence. However, the reverse ranking would require an unquantified amount of negative evidence to reach the target ranking.

[84] MARKEDNESS » FAITHFULNESS rankings (individual or overall) indicate that a grammar allows change between the underlying and surface forms, whereas rankings of FAITHFULNESS » MARKEDNESS do not.

language-specific generalizations would be obscured and target-like markedness would fail to be applied to new lexical items, which would be produced with non-target-like faithfulness.

Theoretical expansions that add constraint classes to OT must also be able to account for an initial state structure which includes these constraints. For example, a required restructuring of the MARKEDNESS » FAITHFULNESS initial state ranking may result from separate classes of input-output (IO) FAITHFULNESS versus output-output (OO) FAITHFULNESS. IO-FAITHFULNESS constraints directly compare input and output forms and the relative ranking of these constraints plays a role in optimal candidate formation during GEN. OO-FAITHFULNESS constraints (Benua 1995, 1997; Burzio 1994; among others) on the other hand compare outputs to other output forms and are only active post GEN. In general, while these separate classes of FAITHFULNESS may be relatively ranked, they still need to initially rank below MARKEDNESS constraints. Sympathy (McCarthy 1999) is a theoretical expansion that requires just such a distinction between these types of FAITHFULNESS constraints. Dinnsen *et al*. (2000) propose that the class of SYMPATHY constraints—special OO-FAITHFULNESS constraints—should be ranked between MARKEDNESS and IO-FAITHFULNESS, for an overall initial state constraint ranking of MARKEDNESS » SYMPATHY » FAITHFULNESS. They suggest that this ranking is necessary for reasons of learnability. Similar to an initial FAITHFULNESS » MARKEDNESS ranking, an initial state of OO-FAITHFULNESS » MARKEDNESS » IO-FAITHFULNESS would struggle with motivating re-rankings between

OO-FAITHFULNESS and MARKEDNESS. Thus language learnability appears to also motivate an initial ranking of MARKEDNESS » OO-FAITHFULNESS » IO-FAITHFULNESS.

Recall from chapter 1 that PRECEDENCE constraints can be considered a type of OO-FAITHFULNESS in the sense that they do not play a role in *forming* candidate chains, but merely evaluate the set of possible output chains at a post-GEN (i.e., output) stage. McCarthy (2007) suggests that a viable initial state ranking would be MARKEDNESS » FAITHFULNESS » PRECEDENCE since such an initial state is compatible with forming the required metaconstraint ranking. However, Wolf (2008) claims that the class of PRECEDENCE must be ranked over FAITHFULNESS for reasons of language learnability and suggests PRECEDENCE » MARKEDNESS » FAITHFULNESS. I argue that an initial ranking of MARKEDNESS » PRECEDENCE » FAITHFULNESS (also suggested independently by Tihonova 2009) is necessary to account for both the emergence and disappearance of non-target opacity in early L1 productions. Importantly, a ranking of MARKEDNESS » PRECEDENCE » FAITHFULNESS would *not allow* the metaconstraints initially. Only more developed grammars would have the overall FAITHFULNESS » PRECEDENCE ranking that permits metaconstraints to form. However, the developmental opacity analyses in chapter 2 and 3 suggest that these grammars require an initial ranking of PRECEDENCE » FAITHFULNESS to ensure that all sequential process applications can be restricted in early grammars.

4.3. Stages of child development and acquisition

In this section, I illustrate the types of constraint re-rankings which define developmental stages during early child acquisition with data from a multi-stage diary study by Ettlinger (2009). The productions in (1) come from child M at various ages ranging from 1;0 to 1;7. Similar to Amahl (Smith 1973), M's utterances exhibit two potentially interacting markedness processes: fricatives becoming stops (stopping) and coronal segments becoming velar segments (velarization). However, the contexts for these non-target processes differ from the contexts for Amahl's. M also exhibits consonant harmony, which appears to overlap with velarization in several utterances. Ettlinger (2009) provides a representative summary of three stages around a potential, but unattested, *s>t>k* chain shift in M's production in (1).

(1)	child M	Stage 1 (1;0-1;4)	Stage 2 (1;4-1;7)	Stage 3 (1;7+)
a.	*cookie*	[kʊ.ki]	[kʊ.ki]	[kʊ.ki]
b.	*talk*	[kʌk][85]	[kʌk]	[tʌk]
c.	*sock*	n/a	[tɑk]	[tɑk]
d.	*table*	n/a	[tej.bo]	[tej.bo]

Ettlinger's (2009) study is particularly interesting in terms of capturing early output forms over a range of stages of production. As discussed in chapter 2,

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85 While productions such as *talk* [kʌk] and *cat* [kæk] raise a question regarding /t/ → [k] being motivated by consonant harmony or velarization, Ettlinger explicitly rules out it being just a velar context effect since velarization of coronals is also found in words such as *tv* [ki.bi] and *tail* [ke.ow].

Ettlinger suggests that what appears to be opacity in child M is really the result of lexical optimization and not opacity. As briefly discussed in chapter 2, under such a claim, we could suppose that velarization produces [kʌk] from underlying *talk* in Stage 1. However, since [tɑk] is the grammatical output for *sock*, we can further suppose that velarization is no longer active by Stage 2. We can explain child M's continued production of [kʌk] instead of [tʌk] as temporarily fossilization of this word. Importantly, if these forms are not the result of opaque process interactions, they do not require additional formal mechanisms to prevent a chain shift sequence and can receive straightforward OT representations. Of course, such an account hinges on a supposition that stopping and velarization are not both active at the same time and that forms derived from application of one process are merely retained as lexical forms after the process has ceased to act upon new forms.

However, Ettlinger also mentions that /tiθ/ is produced as [kik] at 13 months and /ti.vi/ is produced as [ki.bi]. If only one process was available, as is assumed for the opaque outputs, then these forms would be expected to appear in the grammar exhibiting application of either stopping or velarization, but not both, as shown in (2)(a-b). However, the correct outputs in (2)(c) reveal that both velarization and stopping are available. Importantly, since *both* processes act upon the same lexical item, it is a strong indication that they are *concurrently active* in the grammar.

(2) Possible output forms	/ti.vi/	/tiθ/
a) velarization only:	[ki.vi]	[kix]

b) stopping only: [ti.bi] [tit]

c) velarization and stopping: [ki.bi] [kik]

These processes are not acting on the same segments in inputs such as /ti.vi/, and this production remains trivially compatible with simultaneous application. Furthermore, the actual ordering of velarization and stopping is not significant for either lexical item since the final output for both forms is the same regardless of the possible ordering. However, these processes do appear to potentially act on the same segment for /tiθ/ and I turn to comparative representations for both these output forms in further detail in the following discussion of Stage 1.

4.3.1. Stage 1: the (default) initial state

Stage 1 simply follows from the initial state, and thus has the default constraint ranking of MARKEDNESS » PRECEDENCE » FAITHFULNESS. The MARKEDNESS constraints given in (3)(a-c) motivate the processes of stopping, velarization and consonant harmony in M's grammar. Satisfaction of these constraints also triggers violations to the conflicting FAITHFULNESS constraints given in (3)(d-e).

(3) Relevant MARKEDNESS and FAITHFULNES constraints:

a. *FRIC: assign one violation mark for every fricative

b. *[COR]: assign one violation mark for every coronal segment

c. AGREE: assign one violation mark for every consonant segment within a word that does not agree in the feature [PLACE][86]

d. ID[CONT]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [CONT]

e. ID[PLACE]: assign one violation mark for every set of corresponding input-output segments with different values for the feature [PLACE]

The PRECEDENCE constraints relevant to this Stage 1 snapshot involve ID[PLACE] and ID[CONT] and are given in (4). They also have the corresponding metaconstraints of ID[CONT] » PREC(ID[PLACE], ID[CONT]) and ID[PLACE] » PREC(ID[CONT], ID[PLACE]).

(4) *PREC(ID[PLACE], ID[CONT])*: assign a violation mark whenever

(a) a violation of ID[CONT] occurs and is not preceded by a violation of ID[PL], or

(b) a violation of ID[CONT] occurs and is followed by a violation of ID[PL]

PREC(ID[CONT], ID[PLACE]): assign a violation mark whenever

(c) a violation of ID[PL] occurs and is not preceded by a violation of ID[CONT], or

(d) a violation of ID[PL] occurs and is followed by a violation of ID[CONT]

The constraint ranking at the time of child M's first productions is still expected to roughly follow the initial state ranking of MARKEDNESS » PRECEDENCE » FAITHFULNESS. Language learning which has occurred at this this Stage is reflected in targeted re-

[86] This could also include agreement for [CONT], but those violations are redundant with *FRIC here.

rankings within the classes of constraints as opposed to re-ranking occurring between these classes. In keeping with MARKEDNESS » FAITHFULNESS, stopping (i.e., /sɑk/ → [tɑk]) is motivated by a ranking of *FRIC » ID[CONT], where ID[CONT] is violated to satisfy *FRIC. Velarization (i.e., /kæt/ → [kæk]) is motivated by a ranking of *[COR] » ID[PLACE], where ID[PLACE] is violated to satisfy *[COR]. Consonant harmony is similarly motivated by AGREE » ID[PLACE]. Additionally, since fricatives are ungrammatical, violating *FRIC appears to be worse than violating AGREE or *[COR], giving a relative MARKEDNESS ranking of *FRIC » AGREE, *[COR]. A general MARKEDNESS » PRECEDENCE » FAITHFULNESS ranking produces a grammar consistent with transparent application of these processes during Stage 1, as illustrated in (5).[87] Based on these relative rankings, velarization is the only harmonic consonant change available for input /tɑk/, for a grammatical output of [kʌk][88], and no harmonic consonant changes are available for input /kʊ.ki/. A ranking of MARKEDNESS » PRECEDENCE should select transparently formed output, but not opaque ones.

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87 Transparent output selection is still successful under standard OT, but including PRECEDENCE constraints at this stage provides a more consistent transition between Stage specific rankings.

88 The vowel change in /tɑk/ → [kʌk] can be represented as a conflict between the MARKEDNESS constraint REDUCE and the FAITHFULNESS constraint ID[LOW]. However, it is tangential to application of velarization and stopping and is ignored in subsequent candidate chains and corresponding tableaux.

/tɑk/	*[COR]	REDUCE	ID[PLACE]	ID[LOW]
a <tɑk>	*!	*		
b <tɑk, tʌk>	*!			*
c ☞<tɑk, tʌk, kʌk>			*	*

(5) Transparent output selection during Stage 1

/kʊ.ki/	*FRIC	*[COR]	AGREE	PREC (ID[C], ID[P])	PREC (ID[P], ID[C])	ID [CONT]	ID [PL]
a ☞<kʊ.ki>							
/tɑk/							
a <tʌk>		*!	*				
b ☞<tʌk, kʌk>				*a			*

Since PRECEDENCE constraints do not have an active role in correct (i.e., transparent) output selection at this Stage, we do not have specific evidence regarding whether the clauses are conjoined or split. These Stage 1 outputs do not involve sequences of a process following application of a previous process and therefore cannot incur (b)-clause violations, merely (a)-clause violations for a process failing to be preceded by another. Recall also that the metaconstraints are automatically violated by the default MARKEDNESS » PRECEDENCE » FAITHFULNESS ranking.

We can now return to discussion of the output forms /ti.vi/ and /tiθ/. Although Ettlinger does not specify a time when /ti.vi/ is produced as [ki.bi], it must minimally enter M's vocabulary at a stage when ID[PLACE] is violated to satisfy *[COR]. Stage 1 is at least a possible time for this item to enter M's lexicon and the constraint ranking for Stage 1 from (5) provides a straightforward representation of selection of output [ki.bi] for input /ti.vi/, as shown in (6). Note that although candidates (d) and (e) are represented as three-step chains in order to illustrate application of stopping and velarization, since these processes do not act upon the same segment, there is no necessary stipulation for any type of ordering nor prohibition of simultaneous application. Again, in this scenario, PRECEDENCE constraints can only assign (a)-clause violations, but neither these nor the relevant MARKEDNESS and FAITHFULNESS constraints favor either of the (sequential) candidates showing application of both processes. Under this grammar, the two convergent candidate chains are essentially identical and both are optimal.

(6) Application of stopping and velarization to separate segments

/ti.vi/	*FRIC	*[COR]	AGREE	PREC (ID[C], ID[P])	PREC (ID[P], ID[C])	ID [CONT]	ID [PL]
a <ti.vi>	*!	*	*				
b <ti.vi, ki.vi>	*!		*	*a			*
c <ti.vi, ti.bi>		*!	*		*a	*	
d ☞<ti.vi, ki.vi, ki.bi>			*	*a	*a	*	*
e ☞<ti.vi, ti.bi, ki.bi>			*	*a	*a	*	*

Although the Stage of production for [ki.bi] is unclear, the age of the child (i.e., 13 months) for production of [kik] from underlying /tiθ/ indicates that this is definitely during Stage 1. Application of velarization and stopping is not dependent on any type of specific ordering in (2)(c), but the fact that both can apply to the same segment initially appears to indicate that some type of sequential application may be available. This is especially important since the time when each type of application (i.e., simultaneous or sequential) is available plays a defining role in the stages of development. The possible types of process application are given in (7).

(7) Candidate chains for input /tiθ/:

<tiθ>	no change
<tiθ, tit>	stopping
<tiθ, kix>	velarization
<tiθ, kix, kik>	velarization; *then* stopping
<tiθ, tit, kik>	stopping, *then* velarization
<tiθ, tit, kit>[89]	stopping; velarization

Evidence of sequential versus simultaneous process application was highlighted in chapter 2 through conjoined versus split PRECEDENCE constraints. However, the tableaux in (8), showing conjoined PRECEDENCE constraint clauses, and the tableau in (9), showing split (b)-clause PRECEDENCE constraints, select identical outputs.

(8) Stage 1 grammar showing conjoined PRECEDENCE clauses

/tiθ/	*FRIC	*[COR]	AGREE	PREC (ID[C], ID[P])	PREC (ID[P], ID[C])	ID [CONT]	ID [PL]
a <tiθ>	*!	**					
b <tiθ, kix>	*!			*a			*
c <tiθ, tit>		*!*			*a	*	
d <tiθ, kix, kik>				**a!*b		*	**
e ☞<tiθ, tit, kik>				*a	*a*b	*	**
(f) <tiθ, tit, kit>		*!	*	*a	*a	*	*

[89] Inclusion of the candidate chain <tiθ, tit, kit>, which allows only a single change per segment, in (8) and (9) is discussed separately below.

(9) Stage 1 grammar showing split PRECEDENCE clauses

/tiθ/	*FRIC	*[COR]	AGREE	*ID[P] -THEN- ID[C]	*ID[C] -THEN- ID[P]	ID [CONT]	ID [PL]
a <tiθ>	*!	**					
b <tiθ, kix>	*!						*
c <tiθ, tit>		*!*				*	
d <tiθ, kix, kik>				*b		*	**
e ☞<tiθ, tit, kik>					*b	*	**
(f) <tiθ, tit, kit>		*!	*			*	*

Regardless of successful output selection in (8) and (9), the appearance of both processes acting on the same segment potentially conflicts with our assumption of only simultaneous application at early stages of child development. However, PRECEDENCE constraints only distinguish between the types of possible chains, *not* the actual output form, which is the same regardless of PRECEDENCE constraint violations or even PRECEDENCE constraint activity. This can be seen in the failure of candidate (f), <tiθ, tit, kit>, in each of these tableaux, where only a single process has acted on the relevant segments, in spite of the environment permitting additional changes. Candidate (f) receives identical PRECEDENCE violations in (8) and no PRECEDENCE violations in (9), indicating that the type of sequencing that PRECEDENCE constraints eliminate, i.e., /θ/ → [x]/[t] → [k] may not be available for forming candidate chains in this grammar. This is also consistent with the PRECECENCE constraints not playing a vital role in selecting the optimal outputs in (5) and (6). Instead, /θ/ → [k] may actually be a broad form of incremental change under M's

Stage 1 grammar. The lexical item /tiθ/ enters the child's vocabulary when the ban on coronals, *[COR], the ban on segments that do not match in [PLACE], AGREE, and the ban on fricatives, *FRIC, are all unviolated. [k] is a segment that can simultaneously satisfy all of these MARKEDNESS constraints and is the only harmonic resolution under M's current grammar for ungrammatical /θ/, as shown in (10).

(10) Early grammar showing undominated MARKEDNESS ranking

/tiθ/	*FRIC	*[COR]	AGREE	PREC (ID[C], ID[P])	PREC (ID[P], ID[C])	ID [CONT]	ID [PL]
a <tiθ>	*!	**					
b <tiθ, kix>	*!			*a			*
c <tiθ, tit>		*!*			*a	*	
d ☞<tiθ, kik>				**a	*a	*	**
(e) <tiθ, tit, kit>		*!	*	*a	*a	*	*

4.3.2. Stage 2: demotion of MARKEDNESS

While all output forms in Stage 1 were transparent, during Stage 2 we begin to see evidence of a failure of the processes of stopping and velarization to interact in expected ways (i.e., feeding), producing opaque output forms. By stage 2 some MARKEDNESS constraints have been demoted below PRECEDENCE constraints, but they still rank above the FAITHFULNESS constraints. These are the ranking conditions that allow opaque forms to emerge. In spite of the contexts of these processes differing somewhat from those in Amahl's production, the first part of the (modified) OT-CC analysis for this data quite similar to the one for Amahl's productions. During Stage 2, M produces the output forms in (11).

(11) Stage 2 productions for child M:

a.	stopping (fricatives > stops):	[tɑk]	'sock'	[tʌn]	'sun'
b.	velarization (coronals > velars):	[kʌk]	'talk'	[kæk]	'cat'

Although the interaction of these processes has the potential to form the chain shift *s>t>k*, the full sequence of the chain shift is not attested and this implies some type of restricted or sequential application of these processes. If stopping and velarization apply sequentially to an input form, there are two possible orders:

(12) Velarization happens first:	/sɑk/ 'sock'	/kæt/ 'cat'
velarization	*[xɑk]	[kæk]
stopping	*[kɑk]	*n/a*

(13) Stopping happens first:	/sɑk/ 'sock'	/kæt/ 'cat'
stopping	[tɑk]	*n/a*
velarization	*[kɑk]	[kæk]

Under such a sequential ordering scenario, either ordered interaction between velarization and stopping results in an unattested feeding interaction. However, if the processes apply simultaneously to an input form, and neither process can apply to a modified form at a later stage, the outputs are limited to the forms in (14).

(14) Simultaneous rule application:

a. /sɑk/ → [tɑk] (UR meets structural description of stopping)

↘ *[xɑk] (UR meets structural description of velarization)

b. /kæt/ → [kæk] (UR meets structural description of only velarization)

Under a simultaneous rule application scenario, where the underlying representation meets the structural description for more than one process, non-optimal forms will still be over-generated; however, they will also be ruled out with high rankings of specific MARKEDNESS constraints. In this scenario, an illicit form such as [xɑk] will be eliminated as a successful candidate by incurring violations of the highly ranked constraint against fricatives, *FRIC.

Harmonic Serialism generates the candidate chains in (15) based on the MARKEDNESS and FAITHFULNESS rankings of *FRIC » *[COR], AGREE » ID[CONT], ID[PLACE]. Again, when the input contains a coronal stop, velarization is the only harmonically improving process. However, when the input contains a coronal fricative, multiple harmonically improving processes are possible, as shown in (15).

(15) Candidate chains for input /sɑk/:

<sɑk>	no change
<sɑk, tɑk>	stopping
<sɑk, xɑk>	velarization
<sɑk, xɑk, kɑk>	velarization; stopping
<sɑk, tɑk, kɑk>	stopping; velarization

The failed parallel representation in (16) indicates that inclusion of PRECEDENCE constraint violations is crucial at this stage since they now play an active role.

(16) Standard OT grammar favoring over-application of velarization

/tɑk/	*FRIC	*[COR]	AGREE	ID[CONT]	ID[PLACE]
a <tʌk>		*!	*		
b ☞<tʌk, kʌk>					*
/sɑk/					
a <sɑk>	*!	*	*		
b →<sɑk, tɑk>		*!	*	*	
c <sɑk, xɑk>	*!				*
d ☜<sɑk, tɑk, kɑk>				*	*
e ☜<sɑk, xɑk, kɑk>				*	*

However, we can see in (17) that when PRECEDENCE constraints are included with a relative ranking that obeys the metaconstraints, this grammar still fails to select the correct opaque scenario output.

(17) Incorrect opaque candidate selection under standard OT-CC

/tɑk/	*FRIC	*[COR]	AGREE	ID [CONT]	PREC (ID[P], ID[C])	ID [PL]	PREC (ID[C], ID[P])
a <tʌk>		*	*				
b ☞<tʌk, kʌk>						*	*a!
/sɑk/							
a <sɑk>	*!	*	*				
b →<sɑk, tɑk>		*	*	*	*a!		
c <sɑk, xɑk>	*!					*	*a
d ☜<sɑk, tɑk, kɑk>				*		*	*a!*b
e <sɑk, xɑk, kɑk>				*	*a*b!	*	

In order to ensure the correct output is selected in the opaque case, both metaconstraint rankings must be violated and the PRECEDENCE constraints must be strictly ranked with respect to each other, as shown in (18). However, while this ranking is successful for the opaque scenario, inclusion of the PRECEDENCE constraints is still problematic since violating the metaconstraint ranking fails to select the correct output in the transparent scenario. Where the output is transparent, the most faithful candidate is selected since the PRECEDENCE constraint now has a ranking that allows it to rule out an attested natural language process (velarization) solely based on the ordering of FAITHFULNESS violations.

(18) Correct opaque, but incorrect transparent candidate selection

/tɑk/	*FRIC	PREC (ID[C], ID[P])	PREC (ID[P], ID[C])	*[COR]	AGREE	ID [CONT]	ID [PL]
a ☜<tʌk>				*	*		
b →<tʌk, kʌk>		*a!					*
/sɑk/							
a <sɑk>	*!			*	*		
b ☞<sɑk, tɑk>			*a!	*	*	*	
c <sɑk, xɑk>	*!	*a					*
d <sɑk, tɑk, kɑk>		*a!*b				*	*
e <sɑk, xɑk, kɑk>			*a*b!			*	*

This PRECEDENCE constraint failure indicates that these orderings for FAITHFULNESS constraint violations are acting independently, and this motivates splitting the PRECEDENCE constraint clauses into individual constraints that look at only a single ordering for violation assignments. The PRECEDENCE constraints in (4) can be split into individually rankable (a)-clause and (b)-clause constraints, as in (19) and (20).

(19) PREC(ID[PLACE], ID[CONT]) splits into:

(a) ID[PL]←ID[CONT]: ID[CONT] violation must be preceded by ID[PL] violation

(b) *ID[CONT]-THEN-ID[PL]: no ID[PL] violation after ID[CONT] violation

(20) PREC(ID[CONT], ID[PLACE]) splits into:

(a) ID[CONT]←ID[PL]: ID[PL] violation must be preceded by ID[CONT] violation

(b) *ID[PL]-THEN-ID[CONT]: no ID[CONT] violation after ID[PL] violation

The individual (a)-clause and (b)-clause constraints now replace the conjoined PRECEDENCE constraints in the constraint ranking. Similar to the split PRECEDENCE scenarios in chapter 2, it is the (b)-clause constraints that are essential for eliminating the unattested chain shifts. Consequently, the lower ranked (a)-clause constraints can be omitted for the sake of space. Replacing the PRECEDENCE constraints with the (b)-clause constraints leads to a successful ranking that selects the correct output in both the transparent and the opaque scenarios.

(21) Correct opaque and transparent selection under modified OT-CC

/tɑk/	*FRIC	*ID[P] -THEN- ID[C]	*ID[C] -THEN- ID[P]	*[COR]	AGR	ID[P]	ID[C]
a <tʌk>				*	*!		
b ☞<tʌk, kʌk>						*	
/sɑk/							
a <sɑk>	*!			*	*		
b ☞<sɑk, tɑk>				*	*		*
c <sɑk, xɑk>	*!					*	
d <sɑk, tɑk, kɑk>			*b!			*	*
e <sɑk, xɑk, kɑk>		*b!				*	*

However, this ranking is still not complete and cannot represent all the productions representing Ettlinger's Stage 2 since we would expect output [kej.bo] for input /tej.bl̩/. This can be accommodated by ranking the constraint *[COR] below the conflicting FAITHFULNESS constraint ID[PLACE]. At this point, it is AGREE that selects the output where velarization acts upon coronals. However, where AGREE shows no preference, as in [tej.bo] vs. [kej.bo], the ID[PLACE] violation selects the most faithful form.[90] Importantly, this ranking still selects the correct output form for the transparent and opaque scenarios in (22).

(22) Final modified OT-CC ranking representing Stage 2

/tɑk/	*FRIC	*ID[P] -THEN- ID[C]	*ID[C] -THEN- ID[P]	AGR	ID[P]	*[COR]	ID[C]
a <tʌk>				*!		*	
b ☞<tʌk, kʌk>					*		
/sɑk/							
a <sɑk>	*!			*		*	
b ☞<sɑk, tɑk>				*		*	*
c <sɑk, xɑk>	*!				*		
d <sɑk, tɑk, kɑk>			*b!		*		*
e <sɑk, xɑk, kɑk>		*b!			*		*
/tej.bl̩/							
a ☞<tej.bo>				*		*	
b <tej.bo, kej.bo>				*	*!		

Furthermore, the re-ranking of the earlier vital *[COR] » ID[PLACE] domination is expected to occur fairly late in Stage 2 since it indicates the grammar is advancing toward Stage 3, which is characterized by higher rankings of FAITHFULNESS constraints.

[90] Child M's grammar is also expected to select [ti.bi] over [ki.bi] at Stage 2 for the same reasons.

4.3.3. Stage 3: dominance of FAITHFULNESS

By M's stage 3, her grammar is showing a pronounced preference for more faithful forms. In general, the classes of PRECEDENCE and MARKEDNESS constraints have experienced significant movement. Furthermore, the majority of PRECEDENCE constraint have been sufficiently demoted so they are no longer playing such a vital role in eliminating chain shift candidates. Particular marked structures, such as those containing fricatives, remain ungrammatical through a high ranking of *FRIC and a violable ranking of ID[CONT], but [PLACE] violations are now more severe and this makes velarization ungrammatical.

(23) Stage 3 productions for child M:

a. stopping (fricatives > stops): [tɑk] 'sock'

b. no velarization (i.e., no change): [tʌk] 'talk'

A crucial demotion of AGREE below ID[PLACE] allows this grammar to select more faithful, as well as more transparently formed, outputs regardless of the PRECEDENCE constraint rankings. This can be seen in a partially modified version of the split PRECEDENCE constraint ranking from Stage 2, as illustrated in (24). Another important ranking difference from the final Stage 2 ranking in (22) is that at this point, there is no relative ranking required between *FRIC, *ID[P]-THEN-ID[C],*ID[C]-THEN-ID[P], and ID[PLACE] since none of them assign violations to the correct outputs.

(24) Partial representation of Stage 3 ranking with split PRECEDENCE

/tɑk/	*FRIC	*ID[P] -THEN- ID[C]	*ID[C] -THEN- ID[P]	ID[P]	AGR	*[COR]	ID[C]
a ☞<tʌk>					*	*	
b <tʌk, kʌk>				*!			
/sɑk/							
a <sɑk>	*!				*	*	
b ☞<sɑk, tɑk>					*	*	*
c <sɑk, xɑk>	*!			*			
d <sɑk, tɑk, kɑk>			*b	*!			*
e <sɑk, xɑk, kɑk>		*b		*!			*
/tej.bl̩/							
a ☞<tej.bo>					*	*	
b <tej.bo, kej.bo>				*!	*		

Furthermore, since the (feeding) chain shift candidates can be eliminated through FAITHFULNESS violations rather than requiring high-ranked split PRECEDENCE constraints, it is not clear at this point that it is necessary to violate the metaconstraints or even rank the PRECEDENCE clauses separately. We can determine if there is currently a consistent ranking with conjoined PRECEDENCE clauses by using the comparative tableau in (25). Since *FRIC and ID[PLACE] are unviolated, we immediately have a consistent ranking since these two constraints can eliminate all non-optimal forms. PREC(ID[CONT], ID[PLACE]) is also unviolated, but since it does not add any crucial Ws, it remains free to satisfy the metaconstraint ID[PLACE] » PREC(ID[CONT], ID[PLACE]). The remaining constraints need only be ranked below both *FRIC and ID[PLACE] and do require a relative ranking with each other. This also leaves, Prec(Id[place], Id[cont]) free to satisfy the metaconstraint Id[cont] » Prec(Id[place], Id[cont]). This consistent ranking implies that the metaconstraint is now at least available, whereas it was restricted previously.

(25) Comparative tableau with conjoined Precedence constraints (after RCD)

W~L	*Fric	Id[p]	Prec (Id[c], Id[p])	Id[c]	Prec (Id[p], Id[c])	Agr	*[cor]
<tʌk>~ <tʌk, kʌk>	(0~0)	W (0~1)	W (0~1)	(0~0)	(0~0)	L (1~0)	L (1~0)
<sɑk, tɑk>~ <sɑk>	W (0~1)	(0~0)	(0~0)	L (1~0)	L (1~0)	(1~1)	(1~1)
<sɑk, tɑk>~ <sɑk, xɑk>	W (0~1)	W (0~1)	W (0~1)	L (1~0)	L (1~0)	L (1~0)	L (1~0)
<sɑk, tɑk>~ <sɑk, tɑk, kɑk>	(0~0)	W (0~1)	(0~0)	(1~1)	W (1~2)	L (1~0)	L (1~0)
<sɑk, tɑk>~ <sɑk, xɑk, kɑk>	(0~0)	W (0~1)	W (0~2)	(1~1)	L (1~0)	L (1~0)	L (1~0)
<tej.bo>~ <tej.bo, kej.bo>	(0~0)	W (0~1)	W (0~1)	(0~0)	(0~0)	(1~1)	L (1~0)

We can see in (25) that unlike her Stage 2, by M's Stage 3 it is at least possible for the Precedence constraints to behave in an adult-like manner in terms of the availability of the metaconstraint as well as in allowing the (a) and (b)-clauses to function as a conjoined constraint.[91] We can return to a violation tableau format in (26) for a more developed version of the ranking in (24). The only significant difference between the conjoined Precedence ranking in (26) and the preliminary

[91] I set aside discussion on the types of input that would motivation Precedence clauses to conjoin. But see McCarthy (2007) for reasons why they optimally function together in mature grammars.

split clause ranking in (24) is a necessary ranking of *Fric and Id[place] over Prec(Id[place],Id[cont]). This ranking selects grammatical <sɑk, tɑk> over ungrammatical <sɑk, xɑk> or <sɑk, xɑk, kɑk> and it is required in this tableau because allowing conjoined Precedence clauses forces the (a)-clause violation assignment to play a more prominent role.[92] All other relative rankings result from enforcing the metaconstraint ranking.

(26) Violation tableau representing Stage 3 with conjoined Precedence

/tɑk/	*Fric	Id[p]	Prec (Id[c], Id[p])	Id[c]	Prec (Id[p], Id[c])	Agr	*[cor]
a ☞<tʌk>						*	*
b <tʌk, kʌk>		*!	*a				
/sɑk/							
a <sɑk>	*!					*	*
b ☞<sɑk, tɑk>				*	*a	*	*
c <sɑk, xɑk>	*!	*	*a				
d <sɑk, tɑk, kɑk>		*!		*	*a*b		
e <sɑk, xɑk, kɑk>		*!	*a*b	*			
/tej.bl̩/							
a ☞<tej.bo>						*	*
b <tej.bo, kej.bo>		*!	*a			*	

In (26), we can see a general Faithfulness » Precedence, Markedness ranking emerging in M's Stage 3. Such a ranking not only allows the metaconstraints, but it

[92] The (a)-clause violations were rendered inactive in this scenario through low rankings (i.e., lower than the included constraints) in the split clause representation in (24).

largely emulates adult rankings in overall dominance of FAITHFULNESS constraints. And while M's constraint ranking is not yet identical to adult native English grammar since *FRIC is still highly ranked in her grammar, the overall constraint class rankings have been sufficiently modified so that any future opacity is expected to pattern as either opaque productions that are part of the target language, or as those in other possible adult patterns.

4.3.4. Additional L1 re-rankings across Stages

The Stages defined by specific constraint ranking patterns seen in Child M are also at least partially visible in Joan. While her Stage 1 productions are primarily CV, and thus do not allow coda segment comparisons with her Stage 2, she begins to lose voicing neutralizations in final position around age 2;1. As illustrated by the tokens in (24), voiced codas are produced target appropriately and nasal codas are produced as voiced stops of the same place (at a loss of lexical distinction).

(27) Stage 3 production for Joan (Velten 1943:291)

[tab]	'tub, come'	[ta:d]	'can, child'
[wub]	'rib, rim'	[bud]	'big, bin'
[udz]	'edge'	[dud]	'good'

Since voiced coda segments are now grammatical, we know that the relative ranking of *CODA[VOI] and ID[VOI] must now be ID[VOI] » *CODA[VOI]. Denasalization still occurs, which means the relative ranking of *NAS » ID[NAS] remains. The tableau in (28) indicates that at least the FAITHFULNESS constraint ID[VOI] must now be ranked above ID[NAS] and PREC(ID[VOI], ID[NAS]) in order for the grammar to select <wum, wub> as optimal. The remaining relative rankings merely show how obeying the metaconstraint is no longer in conflict with this grammar.

(28) Stage 3 grammar for Joan: denasalization, but not coda devoicing

/ɹɪb/	*NAS	ID [VOI]	PREC (ID[NAS], ID[VOI])	ID [NAS]	PREC (ID[VOI], ID[NAS])	*CODA [VOI]
a ☞<wub>						
b <wub, wup>		*	*a			*
/ɹɪm/						
a <wum>	*!					*
b ☞<wum, wub>				*	*a	*
c <wum, wum̥>	*!	*	*a			
d <wum, wub, wup>		*		*	*a*b	
e <wum, wum̥, wup>		*	*a*b	*		

Thus, Joan's Stage 3 representation indicates that conjoined PRECEDENCE constraints included in a ranking which obeys the metaconstraint can select here grammatical productions. At this point, Joan's grammar also closely resembles the representation of M's Stage 3 grammar in (26).

Early, non-opaque productions for Amahl reveal that fricatives and [COR][LAT] sequences are ungrammatical; however, there does not appear to be any evidence of interaction between these two processes at this stage. Prior to age 2;1, stopping can be seeing in his production of [maut] for '*mouse*' and [maɪt] for '*mice*'. Rather than being resolved by velarization, treatment of [COR][LAT] sequences appears to involve deletion of /l/, such as [didi] for '*little*'. Furthermore, /l/ realized as [d] may be an indication that a this Stage Amahl is applying stopping in to all [+CONT] segments, including laterals, which is a broader context than just fricatives. These outputs are consistent with a default initial state grammar, as shown in (29).

(29) Stage 1 grammar for Amahl: MARKEDESS » PRECEDENCE » FAITHFULNESS

/maɪs/	*[COR] [LAT]	*[+CONT] (*FRIC)	PREC (ID[PL], ID[CONT])	PREC (ID[CONT], ID[PL])	ID [PL]	ID [CONT]
a <maɪs>		*!				
b ☞<maɪs, maɪt>			*a			*
/lɪtl̩/						
a <lɪtl̩>	*!					
b ☞<lɪtl̩, dɪdi>			*a			*
c <lɪtl̩, dɪkl̩>		*!	*a	*a	*	*
d <lɪtl̩, lɪdi>		*!				
e <lɪtl̩, lɪkl̩>		*!		*a	*	

We can also see evidence of Amahl's grammar transitioning from Stage 2 to Stage 3 as he moves toward non-opaque productions around the age of 2;11. The evolution of his grammar documented in Smith (1973) reveals significant changes to some of his earlier opaque Stage 2 productions, as seen in comparison to his later (i.e., Stage 3) productions in (30).

(30) Amahl's productions during: ***Stage 2*** vs. ***Stage 3***

a. Change in underlying fricative production

	Stage 2	Stage 3
'puzzle'	[pʌ**d**l̩]	[pʌ**z**l̩]
'pencil'	[b̥ɛ**t**l̩]	[pɛn**s**l̩]
'special'	[pɛ**t**l̩]	[spɛ**s**l̩]

b. No change in underlying [CORONAL] > [VELAR] before laterals

	Stage 2	Stage 3
'bottles'	[bɔ**k**l̩d]	[bɔ**k**l̩z]
'handle'	[æŋ**g**l̩]	[hæŋ**g**l̩]
'sandal'	[tæŋ**g**l̩]	[sæŋ**g**l̩]

Target-appropriate productions of fricatives indicates at least a re-ranking of ID[CONT] » *FRIC from Stage 2. The overall ranking in (31), contains conjoined PRECEDENCE constraints in a ranking which obeys the metaconstraint. It also shows significant demotion of *FRIC and a generally high ranking of FAITHFULNESS. This ranking allows fricatives, but still eliminates outputs with [COR][LAT] sequences.

(31) Stage 3 ranking for Amahl: adult-like PRECEDENCE and fricatives permitted

/bɔtl̩z/	ID [CONT]	*[COR] [LAT]	ID [PL]	PREC (ID[PL], ID[CONT])	PREC (ID[CONT], ID[PL])	*FRIC
a <bɔtl̩z>		*!				*
b ☞<bɔtl̩z, bɔkl̩z>			*		*a	*
c <bɔtl̩z, bɔkl̩d>	*!		*	*a	*a	

This ranking initially appears to be less successful with underlying /pʌzl̩/ since it would select [pʌɣl̩] over correct [pʌzl̩]. However, rather than indicating a ranking paradox at this point, this may reflect another aspect of approaching an adult-like grammar: narrowing the context of application of *[COR][LAT] to coronal [-CONT] obstruents. Such narrowing of the environment for application of this constraint is also consistent with Amahl's change in treatment of coronal nasals before laterals. By age 2;11 these also more optimal as coronals, as seen in production of [əunliː] for '*only*'. The general context change for application of *[COR][LAT] is shown in (32).[93]

(32) Stage 3 ranking for Amahl: more context specific application of *[COR][LAT]

/pʌzl̩/	ID [CONT]	*[COR] [LAT]	ID [PL]	PREC (ID[PL], ID[CONT])	PREC (ID[CONT], ID[PL])	*FRIC
a ☞<pʌzl̩>						*!
b <pʌzl̩, pʌdl̩>	*!	*		*a		
c <pʌzl̩, pʌɣl̩>			*!		*a	*!
/oʊnliː/						
a ☞<əunliː>						
b <əunliː, əuŋliː>			*!		*a	

Therefore, like Joan and M, we can see that Amahl's grammar can be traced through 3 Stages of development based on changes in output productions.[94]

[93] The chain shifts from Stage 2 are excluded since they no longer represent harmonic changes. However, a candidate formed by application of stopping is included to illustrate how it is eliminated.

[94] Pre-opacity and post-opacity productions were not given for child S.H or child 1.

4.4. Opacity as a developmental stage effect

We can track the changing role of PRECEDENCE constraints over the typical developmental stages of child M. While PRECEDENCE constraints were relatively inert during Stage 1, not only are they vitally important during Stage 2, but they need to be ranked separately to show independent activity for the individual clauses.[95] By Stage 3, however, we can see that the PRECEDENCE constraints now function in early grammars similar to how they function in mature grammars in that they obey the metaconstraint and they can be successfully ranked with conjoined clauses. Post Stage 3 we have seen that PRECEDENCE constraints continue to play a vital role in languages that produce opaque output forms, whether final state or developing.

We can now return to the differences between patterns of opacity occurring in early typical child phonological development and opacity occurring in children with phonological delays. The primary question is whether children with phonological delays pass through the same early developmental stages at similar chronological ages, or if the developmental stages that typically developing children pass through are correspondingly postponed in children with phonological delays. To answer this question I compare the developmental stages which are significant to the emergence of opaque forms in typically developing children to the developmental stages responsible for opacity in phonologically delayed children in the following sections.

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[95] I defer the question of whether PRECEDENCE constraints are already split in the initial state, or the split is triggered by language input, to §4.5. However, including either split or conjoined PRECEDENCE constraints in the initial stage ranking (Stage 1) does not change the output selection.

4.4.1. Typical development constraint rankings

We have seen that the early typical phonological development cases seen in Amahl, Joan and child 1 in chapter 2, child S.H. in chapter 3, and child M in §4.3 appear to pass through development stages defined by overall rankings between constraint classes. These cases represent all the clearly identified early child opacity scenarios available to this study. The source, and life-cycle of non-ordered opacity in these early acquisition cases can be tracked through the stages of gradual constraint demotion show in (33). Since this is based on the initial state, all children are predicted to pass through similar acquisition stages, regardless of the target L1.

(33) Stages of child development and opacity

a. ***Stage 1***: initial constraint inventory

M_1, M_2, M_3 » PREC(F_1, F_2), PREC(F_2, F_1) » F_1, F_2, F_3

b. ***Stage 2***: partial demotion of MARKEDNESS

M_3 » PREC(F_1, F_2), PREC(F_2, F_1) » M_1, M_2 » F_1, F_2, F_3

c. ***Stage 3***: further demotion of MARKEDNESS and PRECEDENCE

M_3, F_1, F_2 » PREC(F_1, F_2), PREC(F_2, F_1) » M_1, M_2 » F_3

As previously proposed, Stage 1 here is essentially the initial state with no re-ranking between constraint classes. The initial state ranking of MARKEDNESS » PRECEDENCE » FAITHFULNESS means the metaconstraints are unavailable initially. Although this permits at least one condition for the non-ordered opacity that appears to be restricted in in later grammars, by itself it does not appear to produce opacity. In Stage 2, some, but not all, of the MARKEDNESS constraints have been demoted below relevant PRECEDENCE constraints, but there is still a general ranking of PRECEDENCE » FAITHFULNESS. This re-ranking introduces the second condition for non-ordered opacity and it is the stage where it is predicted to emerge. This is precisely the constraint ranking format for Amahl, Joan, the Korean L1 learners, child 1 and child M, repeated in (34) and (35). Non-ordered opacity patterns are predicted to occur in child grammars until PRECEDENCE has been demoted below FAITHFULNESS. Additionally, since this stage is primarily determined by the initial state ranking, the opacity effects of this ranking are expected to emerge regardless of the target L1. Such a claim is minimally supported by non-ordered opacity emerging across both English L1 (Velten 1943; Smith 1973; Ettlinger 2009; Barlow and Keare 2008) and Korean L1 (Cho and Lee 2003). At the time of their opaque productions, these children have ages ranging approximately from 1;4 to 2;11.

(34) Stage 2 rankings allowing under-application productions[96]

a. constraint ranking for Amahl (2;2 – 2;11):

*FRIC » PREC(ID[C], ID[PL]), PREC(ID[PL], ID[C]) » *[COR][LAT] » ID[CONT], ID[PL]

b. constraint ranking for Joan (1;10 – 2;1):

*NAS » PREC(ID[N], ID[V]), PREC(ID[V], ID[N]) » *CODA[VOI] » ID[NAS], ID[VOI]

[96] In each of these grammars, the PRECEDENCE constraints have been split and it is really the (b)-clause that receives the ranking shown here. However, these still fall under PRECEDENCE constraints.

c. constraint ranking for child S.H. (1;7 – 2;0):

*[COR] » PREC(ID[C], ID[P]), PREC(ID[P], ID[C]) » *FRIC » ID[PLACE], ID[CONT]

d. constraint ranking for child M (1;4 – 1:7):

*FRIC » PREC(ID[C], ID[P]), PREC(ID[P], ID[C]) » *[COR], AGREE » ID[CONT], ID[PL]

(35) Stage 2 rankings allowing over-application productions

a. constraint ranking for child 1(~2;5):

*C[+VOI], PREC(ID[L], ID[V]) » *V̌C[+VOI] » PREC(ID[V], ID[L]) » ID[VOI], ID[LEN]

By Stage 3, a significant number of PRECEDENCE and MARKEDNESS constraints have been demoted below conflicting FAITHFULNESS constraints, allowing at least a mixed ranking of FAITHFULNESS » PRECEDENCE. While this stage may not be the final-state grammar, it is similar to the target grammar in certain important respects. Namely, this is the stage that has the right conditions for allowing the metaconstraint to form. By Stage 3 non-ordered opacity disappears, along with the conditions which allow it, and any future emerging opacity should be subject to adult-like restrictions. A testable prediction here is that once the metaconstraint is available in a grammar, a learner should not be able to acquire the non-ordered opacity found in early L1-acquisition stages.[97] While many stable grammars have mixed constraint class

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[97] This prediction could be investigated using laboratory (artificial) language learning experiments, e.g., looking at the success of adult acquisition for ordered opacity versus non-ordered opacity. Using an artificial language to test acquisition of opacity has a precedent in Ettlinger (2008) who looked at learning biases for acquiring patterns of counterbleeding opacity versus counterfeeding opacity.

rankings similar to Stage 3, a fourth stage is hypothetically possible for a language with no opacity. In such a language, the set of PRECEDENCE constraints would be entirely demoted below the sets of FAITHFULNESS and MARKEDNESS constraints.

4.4.2. Phonological delay constraint rankings

The productions of phonologically delayed children often provide an opportunity to observe or test hypotheses about stages of child language development using methods which would be difficult with younger children (Dinnsen *et al*. 2000; Dinnsen *et al*. 2011). Among other age related testing advantages, older children have better attention spans and can be prompted to elicit specific outputs. However, as seen in chapter 3, early opaque productions in phonologically typical children are distinct from opaque productions in phonologically delayed children. This distinction suggests that delayed development grammars are not necessarily equivalent to typical early acquisition grammars. In spite of both types of grammars passing through externally similar stages of production, there are important developmental differences.[98]

The phonologically delayed opacity scenarios in Chapter 3 reveal that the non-ordered opacity seen during early L1 acquisition no longer appears to be available to children of more advanced age (i.e., > 3;0). Rather, these children were shown to produce adult-like opacity patterns. Crucial differences between the typical

[98] Since the opacity pattern contrast age is 3;0, the critical period for OT is assumed for both groups and the differences between these groups is attributed to exposure to language input by these ages.

phonological development grammars and the delayed phonological development grammars stem from interaction between FAITHFULNESS and PRECEDENCE. Since the phonologically delayed children produce opaque forms, they appear to be advanced at least beyond Stage 1. And while evidence of non-target and (presumably) temporary acquisition opacity may indicate that they are not fully at Stage 3, the grammars of these children certainly reveal demotion of both MARKEDNESS and PRECEDENCE constraints, which is characteristic of Stage 3. The constraint rankings for the counterbleeding and counterfeeding scenarios exhibited by the delayed development children are repeated in (36) and (37), along with more generic ranking representations.

(36) Delayed development counterbleeding ranking:

a. *CODA » MAX » PREC(ID[WT], MAX) » LENGTHEN » ID[WT] » PREC(MAX, ID[WT])

b. M_1 » F_1 » PREC(F_2, F_1) » M_2 » F_2» PREC(F_1, F_2)

(37) Delayed development counterfeeding ranking:

a. ID[CONT], *[GRVD] » ID[GRVD] » PREC(ID[COR], ID[GRVD]) » *[DENT] » ID[COR] » PREC(ID[GRVD], ID[COR])

b. F_1, M_1 » F_2 » PREC(F_3, F_2) » M_2 » F_3 » PREC(F_2, F_3)

We can see that when these constraint rankings are compared to the representative ones from Stage 2 and Stage 3, repeated here as (38) and (39) below, these rankings share a much closer resemblance to Stage 3 than Stage 2, particularly in the crucial aspect of FAITHFULNESS constraints ranked over PRECEDENCE. This allows the adult-like metaconstraint, still restricted in Stage 2, to form in these grammars.

(38) ***Stage 2***: M_3 » PREC(F_1, F_2), PREC(F_2, F_1) » M_1, M_2 » F_1, F_2, F_3

(39) ***Stage 3***: M_3, F_1, F_2 » PREC(F_1, F_2), PREC(F_2, F_1) » M_1, M_2 » F_3

Recall from chapter 3 that the children in both studies were considered to be typically developing in all respects except for evidence of a phonological delay. As such, I assume that the majority of their language development proceeds in a relatively typical fashion, with certain atypical exceptions. We know that minimally, adult grammars are expected to have the essential constraint re-rankings of Stage 3 since this Stage has the right conditions for the patterns of opacity which appears in mature languages. Since we have seen that the opacity produced by the phonologically delayed children can be analyzed in the same way as final state adult grammar opacity, we have strong support for a claim that their grammars too have gone through the primary constraint class re-rankings necessary to reach Stage 3. And finally, since these essential class re-rankings should not be reversible (for reasons of positive language evidence), adult L2 interlanguage grammars should also be at least at Stage 3. Thus, emergent interlanguage opacity is shaped by adult-like restrictions, as seen in the adult L2 learners discussed in Chapter 3.

Ultimately, typically developing children and phonologically delayed children are expected to pass through the same early language development stages, i.e., Stages 1 through 3, in a similar manner and both are expected to develop grammars that eventually constrain otherwise unattested opacity, such as non-ordered patterns. As such, the account I have developed here predicts that children with phonological delays have already passed through the developmental stage that creates the conditions for non-ordered opacity by the time of observation.[99] Phonologically delayed children do still produce opaque outputs, but these appear to primarily result from MARKEDNESS and FAITHFULNESS constraint rankings that are atypical for the child's age. Similarly, non-target MARKEDNESS and FAITHFULNESS constraint conflicts which emerge in L2 grammars would *reintroduce* non-target opacity during adult interlanguage developmental stages.

4.5. Constraint Compression in the initial state

In addition to the role a default constraint class hierarchy plays in the initial state, the specific form of the constraints initially available to assign violations and participate in re-ranking may also play an important role. In this section, I outline a proposal for a system of Constraint Compression (Waybright 2011), where the

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[99] The approximate chronological limit for the emergence of non-ordered opacity appears to be before 3;0. The early child data in this study reveals no evidence of this type of opacity past this age; all the children who participated in the phonologically delayed studies are greater than 3;0.

initial state is comprised of the most stringent constraint forms.[100] Under this constraint inventory, only the most unmarked forms can be produced. An initial constraint inventory made up of the most stringent constraint forms is consistent with general observations of first language acquisition where the initial state output is the least marked universally.[101]

4.5.1. Gradual access to subconstraints

Under the system of Constraint Compression, the acquisition process involves both constraint re-ranking and constraint *explosions*. When the conflict between input and output demands a more minutiated representation for possible output forms, a relevant constraint effectively explodes by *splitting* the set of possible violations for that constraint into a set of subconstraints defined by non-overlapping proper subsets of the initial set of possible violations. For example if voiceless, but not voiced, codas are permitted, the MARKEDNESS constraint *CODA is too strict and could explode into *CODA[+VOI] and *CODA[-VOI]. At this point, the more stringent *CODA is represented in the grammar by subconstraints that together fully account for the set of possible violation assignments for *CODA, but which can be given separate rankings (i.e., high ranked *CODA[+VOI] but low ranked *CODA[-VOI]).

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[100] The initial motivation for Constraint Compression involved a conflict between *strict domination* (Jusczyk, Smolensky and Allocco 2002) and rankings for constraints in a stringency relationship. However, this aspect is largely set aside here to focus on the impact on early child generalizations.

[101] This approach is also compatible with studies showing an overall initial state constraint ranking of MARKEDNESS » FAITHFULNESS (Jusczyk, Smolensky and Allocco 2002; Gnanadesikan 1995, 2004).

Constraint explosions continue during language acquisition until the constraint inventory and the constraint ranking match that of the target grammar.

Evidence of minutiated coda restrictions can be seen in natural language. Again, when all codas are illicit, the general form of *CODA is sufficient to restrict them in a grammar. Such a restriction on any type of coda production can be seen in early L1 grammars and even some mature grammars, such as Hawaiian. However, many languages, such as Mandarin, Thai and Japanese, allow only a restricted set of coda segments (Broselow, Chen & Wang 1998; Hancin-Bhatt 2000, 2008). These languages cannot be represented with just *CODA since an inviolate ranking restricts all coda segments and a violate ranking fails to distinguish between types of coda segments. Constraint Compression posits that when a grammar only permits a restricted set of coda segments, *CODA explodes into subconstraints that restrict subclasses of coda segments. An illustrative explosion can be seen in Figure **1**, where *CODA explodes into subclass constraints based on MANNER.

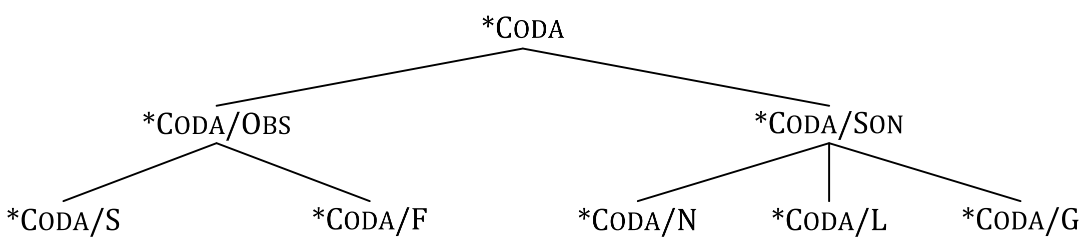

Figure 1: MANNER hierarchy and explosion pattern for *CODA

The *CODA explosion pattern in Figure **1** is based on a natural language preferences for distinguishing coda segments based on MANNER (Clements 1992; Gnanadesikan 1995; Fikkert 1998; Hayes 1999; Broselow and Xu 2004).[102] If required, these multiple subconstraints can in turn individually explode into their own sets of subconstraints until constraints for individual segments, such as *θ, are reached. These multi-tiered explosions contrast with the PRECEDENCE constraint splitting seen in chapters 2 and 3, which was limited to only a single split and two subconstraints. Since the focus for PRECEDENCE constraints is assigning violations based on the orderings of FAITHFULNESS violations, we may expect them to pattern somewhat differently in terms of motivation for splitting from MARKEDNESS and FAITHFULNESS[103] constraints, which typically assign violations based on structure. However, the same principles and motivations for splitting *CODA apply to PRECEDENCE constraints. In both cases, a specific subset of the original constraint violations must be separately rankable in order to accurately represent the grammar. Failure to do so prompts the grammar to explode a constraint into its subconstraints (as defined by violation subsets).

While the entire range of possible constraint forms is not immediately available in the initial state, all constraint forms can eventually be made available when required by language input. Therefore this proposal is not incompatible with

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[102] A structural markedness continuum can be inferred through an increase of coda segment markedness from right to left and this may also result in a preliminary markedness ranking of these subconstraints when they first enter the constraint inventory.

[103] An example of a FAITHFULNESS constraint exploding is given in the following section.

proposals such as the *Completeness Hypothesis*, which states that every grammar explicitly includes all members of CON (Green 1993). It is also consistent with a nativist interpretation of Prince and Smolensky's (1993) proposals for Optimality Theory, which claims that all language learners are born with a complete set of universal constraints. The complete set of universal constraints is included, albeit in a compressed form. Following a learnability approach, constraint explosion is merely an additional step in forming the final ranking hierarchy and it can utilize the same triggers necessary to motivate constraint re-ranking. As long as re-ranking can produce the correct outputs, the subset constraints are not required in the inventory and they remain hidden from the rankable inventory under the most stringent form (i.e., they are *compressed* under this form). It is only when the correct output cannot be selected by any possible ranking of the available constraints that the errors between target and actual output triggers constraint explosion.

This proposal of constraints exploding (and being compressed) in some fashion follows Lombardi (2000, 2003), who claims that constraints are exploded based on language input, Baković (2007) who suggests a necessary split for MAX-C to regulate different types of consonant deletion, and de Lacy (2002, 2004), who proposes constraint conflation in language specific patterns. Green (1993) also proposes a type of metaconstraint in relation to the fact that constraints come in families, and Piñeros' (1999) discusses the motivation for a constraint explosion of FAITH(IV) into STAY(IV) and RESIST(IV). But while specific forms of constraint hierarchies for stringency constraints have been previously suggested (de Lacy 2002, 2004;

Gouskova 2004), an internal compression hierarchy for constraints has not (see Waybright 2011 for details).

4.5.2. Acquisition motivated constraint explosion

Developed grammar support for acquisition motivated constraint explosions comes from second language studies by Lombardi (2000, 2003). Lombardi (2003) examines substitution patterns in languages with stop/fricative distinctions in an OT analysis of substitution for English interdentals. She specifically looks at violations of the IDENT[MANNER] constraint, which assigns a violation for any change in manner in a segment between the input and the output. Lombardi finds that based on language specific evidence, this constraint can explode into the less stringent versions of IDENT[+CONT] and IDENT[-CONT].[104] Lombardi also suggests that while every language starts out with the unitary constraint IDENT[MANNER], once this constraint has been exploded it is no longer a part of the grammar. An even more stringent initial state assumption would be that IDENT[MANNER] is a subset constraint of the most general constraint form, IDENT(F), which is defined as a family of constraints that prohibit changing feature values for each distinctive feature (F). A plausible representation of a stringency constraint hierarchy for IDENT(F), can be seen in Figure **2**. The explosion of IDENT(F) into the less stringent versions of

[104] Lombardi uses Ident(cont) and Ident(stop). She also includes Ident(strident) in this list, but that is perhaps more accurately represented as a subset constraint of Ident(cont), and indeed, Lombardi assigns an Ident(cont) violation to /s/ based on this assumption of a stridency violation.

IDENT[+CONT] and IDENT[-CONT] can be seen in the 2nd tier of Figure **2**. The remainder of Figure **2** represents the subset relation of IDENT[MANNER] to IDENT(F).

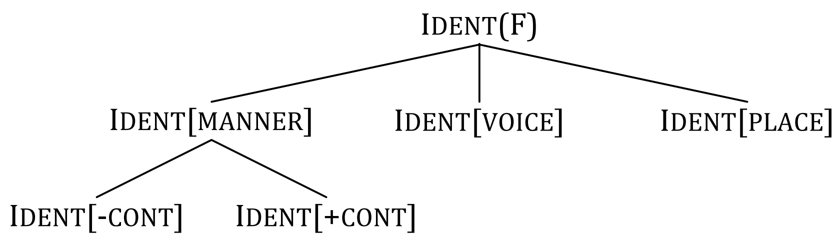

Figure 2: Constraint hierarchy partially based on Lombardi (2003)

For an input of /θ/, Lombardi finds that there are predictable patterns of substitution of the more marked /s/, seen in Japanese, German and Egyptian Arabic, or the less marked /t/, seen in Thai, Russian and Hungarian, based on whether the L1 has exploded the IDENT[MANNER] constraint or not. Restriction of /θ/ is shown with the highly ranked specific segment restriction constraint *θ[105] in both (40) and (41). We can see in (40) that when IDENT[MANNER] has not been exploded in the L1, the language learners substitute the less marked segment of [t]. In such a scenario, the highly ranked constraint *θ remains unviolated and candidates with [s] and [t] match in number of IDENT[MANNER] violations, so the winning candidate is selected based on *[+CONT] violations.

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[105] Lombardi indicates restriction of /θ/ with the specific segment constraint *θ. See Waybright (2011) for an alternative representation of the stringency relationship between *θ and *[CONT].

(40) IDENT[MANNER] has not been exploded and [t] is substituted for /θ/

/θ/	*θ	ID[MANNER]	*[+CONT]	*[-CONT]
a [θ]	*!		*	
b [s]		*	*!	
c ☞[t]		*		*

Only when IDENT[MANNER] constraint has been exploded to its (violation) subset constraints will the language learners substitute [s], as shown in (41).

(41) IDENT[MANNER] has been exploded and [s] is substituted for /θ/

/θ/	*θ	ID[+CONT]	ID[-CONT]	*[+CONT]	*[-CONT]
a [θ]	*!			*	
c ☞[s]				*	
b [t]		*!			*

Again, *θ is unviolated, but the IDENT[+CONT] violation for [t] causes [s] to be chosen as the optimal candidate. Significantly, it is not a specific ranking of the constraints IDENT[+CONT] and IDENT[-CONT] constraints in these tableaux that determines selection of [t] versus [s], rather is their individually rankable violations.

Lombardi does not mention possible explosions of MARKEDNESS constraints in order to reach the specific segment constraint of *θ. However, under Constraint Compression, this specific constraint would result from multiple explosions of more general constraints. The MARKEDNESS constraint *[+CONT] (Lombardi's *cont) assigns a violation to any continuant segment and is a good candidate for a superset constraint for the continuous interdental restriction *θ. Figure **3** provides a partial possible explosion pattern for *[+CONT].

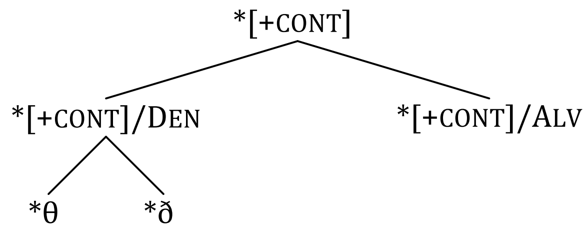

Figure 3: Possible partial explosion pattern for the constraint *[+CONT][106]

In order to include the highly specific constraint *θ, *[+CONT] exploded into subset constraints *[+CONT]/DEN (no dental continuants), *[+CONT]/ALV (no alveolar continuants) and other related subset constraints. An additional explosion of *[+CONT]/DEN produced the segment level constraint *θ.

Although Lombardi only focuses on the explosion of a single faithfulness constraint, her studies provide important evidence from language acquisition for the existence of constraint inventories both with a non-exploded version and with an exploded version of the IDENT[MANNER] constraint. When the IDENT[MANNER] constraint has not been exploded in the L1 the learners interlanguage grammar only assigns a single violation for surface [t] from underlying /θ/. Only when the IDENT[MANNER] constraint has been exploded to the subset constraints of

[106] Lombardi's analysis forces a ranking of the MARKEDNESS stringency constraints *[+CONT] and *θ. However, this can be avoided based on the explosion pattern of *[+CONT] in Figure 3.

IDENT[+CONT] and IDENT[-CONT][107], that the more marked surface [s] will receive fewer FAITHFULNESS violations for underlying /θ/. Lombardi's findings also imply that the areas within a grammar that can be represented with fewer exploded constraints are less marked than areas where a greater number of constraint explosions are required. This is partially due to the more marked nature of the more specific constraints introduced to the grammar via explosions. However, the initial inaccessibility of the less stringent constraint forms does not conflict with the *Completeness Hypothesis* (Green 1993) since these constraints remain part of the grammar even when not individually rankable.

4.5.3. Grammar specific incremental and harmonic changes

Under Constraint Compression, the overall state of the constraint inventory has the potential to explain the scope of the changes that occur in early first language. The more stringent the constraint forms are, the broader the generalizations are expected to be. For example, we saw earlier that a language with *CODA can split into the subconstraints *CODA[+VOI] and *CODA[-VOI]. Recall from chapter 2 that Joan's grammar allows codas, but not voiced codas. Thus, her grammar at the time of production would give a high ranking to *CODA[+VOI] and a low ranking to *CODA[-VOI]. This ranking prefers devoicing of any underlying coda segments and thus applies coda devoicing in a broader way than it applies in an adult language such as German. In order to mimic the adult application, *CODA[+VOI] in Joan's grammar

[107] Presumably this occurs in the L1, but it may also be motivated by L2 language evidence.

would need to split into something like *CODAOBS[+VOI] and *CODASON[+VOI]. Inclusion of these constraints would allow her grammar to distinguish between voicing for obstruents and sonorants in coda position; thus coda devoicing could be applied in a much more context specific manner.

Additionally, a grammar with the most stringent constraint forms is also expected to prefer the least marked output forms. A language with just *CODA prefers less marked CV syllables while a grammar with *CODA split into voicing preferences (i.e., *CODA[+VOI] and *CODA[-VOI]) automatically prefers CVC syllables. As such, it changes the nature of the fixes for illicit structure. Thus, the seemingly less incremental choice of a stopping change of [k] for /h/ by the Korean children in chapter 3 (illustrated by child S.H.) can now be viewed as a substitution choice that is determined by the current state and markedness of the grammar. This of course is expected to vary between L1 since the input received by these children would to change the constraint inventory in different ways than English L2 learners, leading to different optimal choices of substitution for illicit segments.

Therefore, the effects of Harmonic Serialism, while still highly dependent on individual incremental changes, are potentially different between grammars at different states of development. Furthermore, limitations on where changes can occur, such as the positional restrictions frequently evident in adult grammars, may not be quite as available at early developmental stages. As a result, an incremental change, while still just a single permissible change for both grammars, may have a very different appearance in a child's grammar. Even the same markedness processes can have different application due to environmental and positional restrictions, making what is not a harmonic change in an adult grammar a harmonic one in a child grammar. Ultimately, whether or not particular constraints have been exploded affects the types of distinctions a grammar is able to make.

4.6. Conclusion

This chapter proposes that stages of child language acquisition can be roughly defined through ranking relationships between constraint classes, as illustrated in §4.3 and §4.4. Another significant type of transformation to the initial constraint inventory, that of constraint explosion, is illustrated in §4.5. These changes act upon (i.e., transform) the initial state as part of the process of learning a language (along with other possible transformations). The nature of these alterations to the underlying constraint structures implies reverting to the initial state should not be possible. Furthermore, once key re-rankings occur, particularly those of FAITHFULNESS in relation to MARKEDNESS and PRECEDENCE, additional input will be insufficient to motivate ranking reversals. It is similarly unclear what type of language input would motivate conjoining the independent subsets of MARKEDNESS and FAITHFULNESS constraints following an explosion/split.[108]

The inability of language input to motivate transformation reversals closely follows error-driven learnability approaches to constraint re-ranking (Tesar and

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[108] This is potentially an important area of difference with PRECEDENCE constraints since the conjoined clause form for PRECEDENCE does appear to be significant in final state grammars.

Smolensky 1996; Pulleyblank and Turkel 1998; Hayes 1999; Prince and Tesar 1999; Boersma and Hayes 2001) where it is the difference between the target output and the output selected by the current grammar that triggers constraint re-ranking. Under such approaches, initial state rankings of FAITHFULNESS » MARKEDNESS will faithfully produce outputs that match the input, but fail to trigger the types of constraint re-ranking that defines individual languages. Under such approaches we again see that a MARKEDNESS » FAITHFULNESS ranking is necessary in order to reveal input/output differences which trigger language-specific re-rankings.

Similarly, once the metaconstraint has been made available through a general FAITHFULNESS » PRECEDENCE ranking, the types of opacity that are encountered in the input from final-state languages will again be insufficient to trigger any type of re-ranking between a PRECEDENCE constraint and its B FAITHFULNESS constraint. Consequently, while certain types of individual constraint re-ranking is always available, the overall constraint class re-ranking and the constraint explosions that are motivated during language learning are essentially irreversible due to the directionality of the input/output disparity trigger. This follows transient phonology claims where the forces that drive child-specific patterns are some way contingent or transient and no longer in effect by the time the child reaches adulthood (McAllister Byun, Inkelas and Rose 2012). Once certain transformations have modified the initial state, the conditions for non-ordered opacity disappear.

CHAPTER 5:
DEVELOPMENTAL OPACITY IMPACT ON OPTIMALITY THEORY

5.1. Introduction

The majority of this dissertation has focused on analyzing the nature of opacity in early child development. However, in this chapter I shift the focus toward the place and role of non-ordered opacity within the broader scope of mainstream OT. Previous chapters have established that this pattern of opaque interactions should be subsumed under the historic and ongoing problem of opacity for standard OT. As such, it is minimally expected to fail under standard OT, consistent with other forms of phonological opacity. A more surprising result from this study was the failure of standard OT-CC representations for early child data. Recall that standard OT-CC has shown impressive success with a range of scenarios for both stable (chapter 1) and developmental (chapter 3) opacity. Furthermore, this failure under OT-CC runs contrary to predictions made by Dinnsen *et al*. (2011) and Barlow and Keare (2008), namely that opaque productions in early acquisition can be represented in the same way as the phonologically delayed opacity introduced in chapter 3. However, we saw that OT-CC analyses of early child productions succeeded only after non-trivial modifications, such as lifting the metaconstraint and separately ranking the PRECEDENCE clauses, had been made to the theory's infrastructure.

Throughout this dissertation, some form of OT-CC has been the primary means of analyzing developmental opacity patterns. Furthermore, formulations of either standard OT-CC or modified OT-CC were specifically used to illustrate the arguments in chapters 2 through 4 regarding a difference between the type of opacity that emerges in chronologically early, but typically developing, grammars (ages of less than 3;0) versus the type that emerges in later developing grammars with phonological delays (ages of greater than 3;0). While OT-CC proved to be an excellent diagnostic for identifying and establishing the non-ordered opacity patterns, nearly exclusive focus on this theoretical extension also has the undesirable consequence of potentially allowing them to be viewed as an artifactual phenomenon emerging as the results of particular aspects of OT-CC. As discussed in chapter 1, OT-CC is far from the only way to represent opacity and there are many diverse theoretical extensions to OT which account for various types of opaque interactions. In order to exclude the possibility that non-ordered opacity is an artifact of specific OT-CC formulations, I now turn to representations of early child opacity under additional theoretical representations. Specifically, I compare analyses of ordered opacity and non-ordered opacity under Sympathy (McCarthy 1999) and Local Constraint Conjunction (Smolensky 1993, 1995; Moreton and Smolensky 2002). Similar to standard OT-CC, a Sympathy analysis of non-ordered opacity fails to allow two processes to individually apply transparently, but still interact opaquely. Local Constraint Conjunction (LCC) has better success with representing non-ordered counterfeeding, but fails to distinguish between ordered and non-ordered opacity. However, I show that the logic behind LCC is ultimately a precursor to the (b)-clause success of modified OT-CC.

The remainder of chapter 5 is organized in the following way. §5.2 will introduce the well-known theoretical extensions of Sympathy and LCC, and show how they analyze the counterbleeding and counterfeeding scenarios introduced in chapter 1. I then compare these results with similar analyses of child opacity (i.e., non-ordered opacity). In §5.3 I provide an overview of how standard OT primarily predicts only transparent (i.e., feeding and bleeding) interactions. I then review how this limitation was partially resolved through select theoretical extensions, such as OT-CC. In chapter 1 we saw that OT-CC expands these predictions to include some over- and under-application interactions (i.e., counterbleeding and counterfeeding). Although key aspects of standard OT-CC, such as the metaconstraint ranking, specifically curtail the types of interactions it predicts to occur in natural language, the non-ordered opacity patterns established in this dissertation reveal that there is an undesirable gap in these predictions. As demonstrated in chapters 2 through 4, this gap can be covered with certain modifications to the theory and I reiterate the expanded process interaction predictions of modified OT-CC in this chapter. Finally, in §5.4 I conclude with an overview of how the findings in this dissertation contribute to our understanding of initial state structure and the stages of first language development.

5.2. Comparisons with other theoretical extensions

The sheer range and theoretical diversity for representation of opaque interactions under an OT framework makes a comprehensive survey of their treatment of non-ordered opacity impractical for this dissertation. However, it is still valuable to see how it is treated under a select few and compare these results with the OT-CC representations we have seen in chapters 2 through 4. Sympathy (McCarthy 1999) and Local Constraint Conjunction (Smolensky 1993, 1995; Moreton and Smolensky 2002) are particularly well-known and are included here largely based on their general presence in mainstream OT and the corresponding amount of opacity literature surrounding them. Furthermore, a greater overall value for each of these extensions within the theory has been established through at least some application to both opaque and non-opaque language aspects.

5.2.1. Sympathy

Sympathy provided one of the earliest representations of phonological opacity under OT, and as such it has potentially the largest body of opacity related literature.[109] Sympathy is essentially an output-output correspondence relation that allows an opaque form to be selected as the optimal candidate through the influence

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[109] Among numerous others, applications of Sympathy to opacity scenarios include counterbleeding in Icelandic (Karvonen and Sherman 1997), counterbleeding in L1 English for phonologically delayed children (Dinnsen *et al*. 2000), nasalization (nasal harmony) under Harmonic Sympathy (Walker 2000), counterbleeding and mutual bleeding in Standard and colloquial German (Itô & Mester 2003), failed counterfeeding chain shifts appearing in Korean/English interlanguage (Eckman *et al*. 2003), counterbleeding in Romanian (Iscrulescu 2006), failed opaque representation for Argentinian Spanish (Kaisse 2009), and counterbleeding in Finnish (Peterson 2014).

of a failed, but transparently formed *sympathetic candidate*. Sympathy requires separate classes of input-output (IO)-FAITHFULNESS and output-output (OO)-FAITHFULNESS since a *sympathetic relationship* is accomplished through a crucial ranking of a particular IO-FAITHFULNESS constraint dominated by a special OO-FAITHFULNESS constraint, designated as a SYMPATHY constraint.[110] The goal of this sympathetic relationship is the preservation of some significant phonological property of the failed candidate. Of course, the importance of the failed candidate lies in its embodiment of a significant intermediate form feature no longer evident in the output, but which was a key aspect of the success of derivational approaches.

5.2.1.1. Adult vs. child over-application

Recall the Tiberian Hebrew counterbleeding scenario introduced in chapter 1, where epenthesis is transparently motivated by a constraint ranking of *COMPLEX » DEP-V, while ʔ-deletion is transparently motivated by a ranking of CODA-COND » MAX-C. However, the conditions which trigger epenthesis in surface [deʃe] are not apparent and the FAITHFULNESS violation incurred by the epenthetic vowel cannot be justified in terms of surface markedness improvement. The failed standard OT tableau from chapter 1 is recreated here as (1).

(1) Failed standard OT counterbleeding tableau for Tiberian Hebrew

[110] The distinction of IO-FAITHFULNESS and OO-FAITHFULNESS is separate from a specific theoretical extension, but similar treatment would be expected from any analysis that relies on multiple levels of FAITHFULNESS application, i.e., input-output comparison versus output-output comparison.

/deʃʔ/	CODA-COND	*COMPLEX	MAX-C	DEP-V
a [deʃʔ]	*!	*		
b ☜[deʃ]			*	
c [deʃeʔ]	*!			*
d →[deʃe]			*	*!

A Sympathy analysis of this counterbleeding scenario works in the following way.[111] In order to determine the influential failed candidate, we need to first designate an IO-FAITHFULNESS constraint as the *selector*. In general, this constraint favors candidates which embody a targeted phonological property and is designated by ✯ (following McCarthy 1999). While the choice of the selector must ultimately be determined on a *language-particular* basis, McCarthy provides some heuristics for making the choice. One heuristic is that only dominated FAITHFULNESS constraints are of interest as selectors since an undominated FAITHFULNESS constraint will simply pick out the candidates that would have won even without Sympathy effects.[112] Possible selectors for Tiberian Hebrew are the dominated FAITHFULNESS constraints: MAX-C, which requires preservation of underlying consonants, and DEP-V, which restricts epenthesis. Another heuristic is that the selector should choose a candidate in which the opaque process is motivated transparently. The selector

[111] While the details of a Sympathy analysis are admittedly a bit onerous at this point, inclusion of the type of machinations required for this theory serves to illustrate the comparative improvements in logic and universal applicability for the theoretical complexity associated with OT-CC.

[112] For arguments in favor of broadening the class of potential selectors to include MARKEDNESS constraints, rather than just FAITHFULNESS constraints, see Itô and Mester (1997) and de Lacy (1998, 2002). Minimally, such arguments imply that the scope of potential selectors is difficult to define. Thus, McCarthy's primary interest is in constraints that allow some type of theoretical limitation.

should at least favor the most faithful output and, usually, an additional failed candidate over the winner.[113] MAX-C favors the fully faithful candidate [deʃʔ] as well as [deʃeʔ], the failed candidate where the opaque process, epenthesis, is transparently motivated by the ranking *COMPLEX » DEP-V. Since MAX-C, marked as ✯MAX-C, satisfies both heuristics, it is a good choice for the selector here.

We can now establish the *sympathetic candidate*, which will be the most harmonic member of the set of candidates that obey the selector. To create the set of candidates the IO-FAITHFULNESS constraint F_i (the selector) sorts the candidate set C into two non-overlapping subsets: $C_{<-F_i>}$, which violate F_i, and $C_{<+F_i>}$, which obey F_i. The input itself is a member of the set of output candidates, ensuring $C_{<+F_i>}$ is non-empty, since it contains at least the fully faithful candidate. McCarthy (1999) gives three main principles for choosing the sympathetic candidate:

(2) Principles for choosing the sympathetic candidate (McCarthy 1999)

a. *Harmonic evaluation:* the sympathetic candidate is the most harmonic member of the subset of candidates available under $\boldsymbol{C}_{<+F_i>}$.

b. *Confinement to* $\boldsymbol{C}_{<+F_i>}$: selection of the sympathetic candidate is confined to $\boldsymbol{C}_{<+F_i>}$, the subset of candidates that obey the designated IO-FAITHFULNESS constraint F_i (the selector).

[113] By favoring the faithful candidate, the selector also contributes to the *recoverability* of underlying representations. See McCarthy (1999) for discussion of counterbleeding opacity recoverability.

c. *Invisibility of SYMPATHY constraints*: selection of sympathetic candidates is done without reference to SYMPATHY constraints.

We have already established that the form [deʃeʔ] has legitimate status in Tiberian Hebrew as a member of the output candidate set created by GEN from input /deʃʔ/ since it is formed through harmonic application of a process (i.e., epenthesis) to break up a consonant cluster. It is also a failed candidate since it still fatally violates the highly ranked MARKENDESS constraint, CODA-COND.[114] Both [deʃeʔ] and faithful [deʃʔ] are in the set of candidates that obey MAX-C; however, [deʃeʔ] is more harmonic than [deʃʔ] since [deʃʔ] violates *COMPLEX as well as CODA-COND. Furthermore, since we do not yet have a SYMPATHY constraint, condition (2c) is satisfied vacuously. Consequently, [deʃeʔ], marked as ❀[deʃeʔ], is an excellent sympathetic candidate in terms of being the most harmonic member of the set of candidates that obey MAX-C (conditions (2a-b), and being favored as an output form that transparently satisfies the ranking, *COMPLEX » DEP-V, which motivates the (opaque) process of epenthesis.

The sympathetic candidate influences the choice of output by entering into a *sympathy relation* with the correct output form via an OO-FAITHFULNESS (i.e., inter-candidate) constraint, the *SYMPATHY constraint*. The SYMPATHY constraint, also marked with ❀, establishes the importance of the relationship between the

[114] [deʃeʔ] is also the candidate that corresponds to an intermediate derivational stage where one process has applied but the ordering/environment still requires application of a second process.

sympathetic candidate and the correct output by favoring some resemblance between these possible output forms. The output [deʃe] and the sympathetic candidate ❀[deʃeʔ] resemble each other in terms of maximizing vowel retention, regardless of both receiving an IO- FAITHFULNESS DEP-V violation.[115] An OO-FAITHFULNESS constraint such as MAX-V, which assigns a violation mark based on whether an output has a vowel segment that corresponds to a vowel segment in a particular output form (i.e., the sympathetic candidate), is a good candidate for a SYMPATHY constraint. Domination of ❀MAX-V over ✭MAX-C ensures favoring maximum vowel retention. The final ranking is given in the tableau in (3), where the candidates that obey the selector are indicated by ✓.

(3) Tableau including SYMPATHY for Tiberian Hebrew counterbleeding

/deʃʔ/	CODA-COND	*COMPLEX	❀MAX-V	✭MAX-C	DEP-V
a [deʃʔ]	*!	*	*	✓	
b [deʃ]			*!	*	
c ❀[deʃeʔ]	*!			✓	*
d ☞[deʃe]				*	*!

The ranking of the SYMPATHY constraint ❀MAX-V is only crucial in terms of dominating the selector constraint ✭MAX-C since its relative ranking with the inviolate constraints CODA-COND and *COMPLEX does not affect selection of the

115 We can say that the epenthetic vowel in [deʃeʔ] creates a closer resemblance to [deʃe] than faithful [deʃʔ] in that [deʃeʔ] → [deʃe] is transparent segment deletion while [deʃʔ] → [deʃe] is not. Thus, ❀[deʃeʔ] resembles the input in maximizing consonants and the output in maximizing vowels.

optimal output. Importantly, when these processes take place transparently, the sympathetic candidate is also the optimal output, so violations for the SYMPATHY constraint are vacuous and do not affect output selection.[116] This can be seen in a recreation of the transparent Tiberian Hebrew tableau from chapter 1 in (4).

(4) SYMPATHY violations with transparent process application

/qaraʔ/	CODA-COND	*COMPLEX	❀MAX-V	✯MAX-C	DEP-V
a [qaraʔ]	*!			✓	
b ☞❀[qara]				*	
/melk/					
a [melk]		*!	(*)	✓	
b [mel]			(*)	*!	
c ☞❀[melex]				✓	*
d [mele]				*!	*

We can now take a look at non-ordered counterbleeding under a Sympathy analysis. Recall the opaque productions of Child 1 (Barlow and Keare 2008) in chapter 2, where vowel lengthening (i.e., /dɔg/ → [dɔːg]) is transparently motivated by a ranking of *V̆C[+VOI] » ID[LEN] while coda devoicing (i.e., /dɔg/ → [dɔk]) is transparently motivated by a ranking of *C[+VOI]# » ID[VOI]. However, the conditions which trigger vowel lengthening in the actual output [dɔːk] are not apparent on the surface since the ID[LEN] violation cannot be justified in terms of

[116] These violations are vacuous since any violations they assign do not alter selection of the candidate chosen by the grammar without the SYMPATHY constraint. However, favoring [melex] over [mel] here justifies a relative ranking of MAX-C » DEP-V, which does play a role in optimal candidate selection.

markedness improvement. The failed standard OT tableau from chapter 2 is repeated here as (5).

(5) Failed standard OT representation of child over-application

/dɔg/	*C[+VOI]	*V̆C[+VOI]	ID[VOI]	ID[LEN]
a [dɔg]	*!	*		
b [dɔːg]	*!			*
c ☜[dɔk]			*	
d →[dɔːk]		*!	*	*!

Our possible selectors are ID[VOI] and ID[LEN] since they are the relevant dominated FAITHFULNESS constraints. The opaque process in this scenario is vowel lengthening, since the final output destroys the environment which triggers it and only ID[VOI] favors the candidate where this process is motivated transparently. This selector also favors the most faithful candidate. In the set of candidates which obey ✫ID[VOI], [dɔːg] violates only one of the highly ranked MARKEDNESS constraints while [dɔg] violates two. Thus, [dɔːg] is the most harmonic member of this set (since it is formed through harmonic application of vowel lengthening) and this is our sympathetic candidate. The next step is to find a SYMPATHY constraint which favors some feature shared by [dɔːg] and [dɔːk]. Since these two candidates resemble each other in terms of vowel length, OO-ID[LEN] seems like a possibility and ranking it over *V̆C[+VOI] eliminates [dɔk]. We can combine these revisions to (5) in (6).

(6) Revised tableau with partial Sympathy representation

/dɔg/	*C[+VOI]	❀ID[LEN]	*V̆C[+VOI]	✯ID[VOI]	ID[LEN]
a [dɔg]	*!	*	*	✓	
b ❀[dɔːg]	*!			✓	*
c [dɔk]		*!		*	
d ☞[dɔːk]			*	*	*

But this ranking needs to generally account for interactions between vowel lengthening and coda devoicing for child 1, and here we run into a significant roadblock. These processes also interact in the diminutive, where /dɔgi/ is produced as [dɔːgi]. Here the sympathetic candidate (i.e., the most harmonic member of the set of candidates which obey ✯ID[VOI]) is ❀[dɔgi], and this grammar also selects it as optimal. Even without a SYMPATHY violation, [dɔːgi] cannot win.

(7) Failed remainder of the Sympathy representation

/dɔgi/	*C[+VOI]	❀ID[LEN]	*V̆C[+VOI]	✯ID[VOI]	ID[LEN]
a ☜❀[dɔgi]				✓	
b →[dɔːgi]		*!	*	✓	*
c [dɔki]				*!	
d [dɔːki]		*!	*	*	*

This failure is due to [dɔːgi] incurring more violations than [dɔgi], which is a direct result of simultaneous application allowing lengthening in an environment it otherwise could not apply. Overall, the inconsistency between these representations stems from simultaneous application generating these outputs without making reference to a preferential sequence. Thus, this non-ordered counterbleeding scenario appears to fail under a SYMPATHY analysis.

5.2.1.2. Adult vs. child under-application

Identification of the selector constraint proceeds in a slightly different way for counterfeeding opacity. Recall the Bedouin Arabic counterfeeding scenario introduced in chapter 1, where epenthesis, i.e., /gabr/ → [gabur], is transparently motivated by a constraint ranking of *COMPLEX » DEP, while vowel raising, i.e., /ka.tab/ → [ki.tab], is transparently motivated by a ranking of **a*CV » ID[LOW]. These processes fail to interact in the feeding output of *[gi.bur], in spite of having the appropriate surface conditions to do so and the correct output is non-raising [ga.bur]. The failed standard OT tableau from chapter 1 is recreated here as (8).

(8) Failed counterfeeding tableau for Bedouin Arabic

/ka.tab/	*COMPLEX	DEP	**a*CV	ID[LOW]
a [ka.tab]			*!	
b ☞[ki.tab]				*
/gabr/				
a [gabr]	*!			
b →[ga.bur]		*	*!	
c ☜[gi.bur]		*		*

The dominated FAITHFULNESS constraint DEP favors the faithful candidate [gabr], which is also the only candidate where the opaque process, the lack of vowel raising in an open syllable, can be considered even close to being motivated transparently. This makes DEP a good candidate for the selector constraint. However, since [gabr] is the only candidate favored by the selector, this failed candidate is necessarily also the sympathetic candidate. The OO-FAITHFULNESS constraint ID[LOW][117] is selected as the SYMPATHY constraint since it favors the sympathetic candidate, [gabr] and the candidate with matching vowel height, [ga.bur]. Ranking the SYMPATHY constraint ❀ID[LOW] over the MARKEDNESS constraint **a*CV, which drives the raising process, blocks raising in open syllables; thus the relative ranking of the SYMPATHY constraint is crucial in terms of dominating **a*CV rather than the selector ✯DEP. The updated violation tableau representation is given in (9).

(9) Opaque scenario with SYMPATHY constraint for Bedouin Arabic

/gabr/	*COMPLEX	✯DEP	❀ID[LOW]	**a*CV	ID[LOW]
a ❀[gabr]	*!	✓			
b ☞[ga.bur]		*		*!	
c [gi.bur]		*	*!		*

Since the sympathetic candidate and the most faithful candidate are the same, Sympathy for the opaque candidate in terms of vowel height restricts raising in the optimal output. However, (9) provides an incomplete representation of Bedouin Arabic productions, and I now turn to a Sympathy analysis of the remainder.

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[117] The ID[LOW] that is already part of the constraint ranking is an IO-FAITHFULNESS constraint. These constraints are distinguished in the constraint ranking via the ❀ indicating the SYMPATHY constraint.

In general, a Sympathy analysis similar to the representation in (3) will be successful with counterbleeding opacity. However, the overall success of Sympathy with counterfeeding opacity is necessarily more qualified. This is largely a consequence of inclusion of a SYMPATHY constraint being dependent on certain conditions being met. These conditions are generally satisfied for counterbleeding opacity, but must be specifically invoked when accounting for counterfeeding opacity scenarios, and crucially not invoked when accounting for transparent process application within the same grammar. This special invocation is directly tied to the way a ranking paradox becomes apparent for counterfeeding scenarios. Unlike counterbleeding interactions, which inevitably fail under a standard OT ranking, a counterfeeding interaction itself is easily represented under standard OT since it only needs to restrict a particular process from applying. Similarly, a ranking that transparently motivates the same process is also easily represented under standard OT. Therefore, rankings that either allow transparent application of a process or restrict application of the same process are unproblematic and, therefore, unrevealing in isolation. Only through juxtaposition of these representations is the ranking paradox, i.e., the ranking conflict, revealed.

While the paradoxical nature of the standard OT Bedouin Arabic rankings (i.e., conflicting rankings of **a*CV and ID[LOW]) is evident, the SYMPATHY paradox is revealed in the following way. Like the transparent scenarios in (4), the most harmonic member of the candidate set which obeys the selector ✯DEP, i.e., the sympathetic candidate, is the correct output [ki.tab]. It initially appears that such a ranking automatically favors [ki.tab] as the optimal output since the SYMPATHY constraint does not assign a violation to the sympathetic candidate, as in (10).

(10) Non-activity of SYMPATHY for transparent scenario in Bedouin Arabic

/ka.tab/	*COMPLEX	✯DEP	❀ID[LOW]	**a*CV	ID[LOW]
a [ka.tab]		✓		*!	
b ☞❀[ki.tab]		✓			*

However, this creates a situation where a grammar has conflicting sympathetic preferences for vowel height since accounting for the counterfeeding interaction requires SYMPATHY for low vowels and the transparent interaction requires SYMPATHY for high vowels. We can resolve this by selecting sympathetic candidates which prefer the underlying vowel feature ([LOW]); thereby making the fully faithful candidates the sympathetic ones in each scenario. But now the SYMPATHY constraint ❀ID[LOW] favors the fully faithful output over the correct one. Therefore, to select the output where raising applies transparently in an open syllable we need to rank ❀ID[LOW] below the constraint that motivates raising, **a*CV, as shown in (11). But of course, this conflicts with the required counterfeeding ranking for ❀ID[LOW] in (12).

(11) Required SYMPATHY ranking for transparent application in Bedouin Arabic

/ka.tab/	*COMPLEX	✯DEP	**a*CV	❀ID[LOW]	ID[LOW]
a ❀[ka.tab]		✓	*!		
b ☞[ki.tab]		✓		*	*

(12) Conflicting rankings with SYMPATHY constraint for Bedouin Arabic

/ka.tab/	*COMPLEX	✯DEP	❀ID[LOW]	*aCV	ID[LOW]
a ☜❀[ka.tab]		✓		*!	
b →[ki.tab]		✓	*!		*
/gabr/					
a ❀[gabr]	*!	✓			
b ☞[ga.bur]		*	*!	*!	
c [gi.bur]		*			*

Clearly, the ranking paradox for counterfeeding scenarios under Sympathy mainly concerns the relative ranking/activity of the SYMPATHY constraint. When the sympathetic candidate is also the fully faithful candidate, i.e., in a *self-sympathetic* relationship, ranking the SYMPATHY constraint over the constraint which motivates this process will not allow the otherwise transparently formed, and correct, output to win. Furthermore, violations for the SYMPATHY constraint cannot be vacuous only when the process takes place transparently. Therefore, a Sympathy analysis will inevitably fail to represent the complete grammar without a certain amount of special stipulation for when the SYMPATHY constraint can be invoked.

We have seen that unlike transparent interactions for Tiberian Hebrew in (4), for the Bedouin Arabic transparent interaction of /ka.tab/ → [ki.tab], the selector ✯DEP does not favor a failed candidate and is therefore not at *stake*. Following McCarthy (1999), we can say that a Sympathy approach for counterfeeding opacity requires an overt stipulation: the SYMPATHY constraint is invoked only when the selector favors a failed candidate (as it does for the opaque scenarios in (3) and (9)) and it must not be invoked otherwise.[118] This type of restricted invocation allows SYMPATHY constraints to play an active role in eliminating unattested feeding interactions, but to remain inert during transparent interactions.

The non-ordered counterfeeding pattern seen in early child productions (Velten 1943; Smith 1973; Cho and Lee 2003; Ettlinger 2009) resembles the Sympathy counterfeeding opacity representation for Bedouin Arabic. However, there are some non-trivial differences. Recall the failed standard OT representation for Joan from chapter 2, recreated in (13). Note that the distinct candidate chains <bun, bud, but> and <bun, bun̥, but> reduce to the single output form [but] under both standard OT and Sympathy since neither has a way to evaluate intermediate changes.

(13) Failed standard OT tableau selecting over-application of devoicing

/bad/	*NAS	*CODA[VOI]	ID[NAS]	ID[VOI]
a [bad]		*!		
b ☞ [bat]				*
/spun/				
a [bun]	*!	*		
b → [bud]		*!	*	
c [bun̥]	*!			*
d ☜ [but]			*	*

[118] Such a stipulation is further supported by a similar analysis of non-surface-true opacity in McCarthy (1999), where the SYMPATHY constraint is invoked when the selector constraint favors multiple candidates. However, the principles behind the concept of invoking a special constraint ranking based on violation of another constraint do not appear to be well-developed in OT.

We first need a selector and in order to choose between dominated ID[NAS] and ID[VOI], we must determine which of these constraints favors the candidate where the opaque process applies transparently. Similar to the Bedouin Arabic counterfeeding scenario, the opaque process here is the *lack* of devoicing. ID[VOI] favors both [bun] and [bud], but [bud] is the most harmonic member of this subset. Like the transparent scenarios in (4), we again have a situation where the sympathetic candidate and the correct output are the same and a SYMPATHY constraint creates a self-sympathetic relationship. The OO-FAITHFULNESS constraint ID[VOI] favors the voiced outputs and ranking it above the constraint that motivates devoicing, *CODA[VOI], selects the correct opaque output form, as shown in (14).

(14) Sympathy tableau for Joan with ✮ID[VOI] and ❀ID[VOI]

/bad/	*NAS	❀ID[VOI]	*CODA[VOI]	ID[NAS]	✮ID[VOI]
a ☜❀[bad]			*		✓
b →[bat]		*!			*
/spun/					
a [bun]	*!		*		✓
b ☞❀[bud]			*	*	✓
c [bun̥]	*!	*			*
d [but]		*!		*	*

Similar to the Bedouin Arabic counterfeeding representation, we can see that it is necessary for the fully faithful output to be the sympathetic candidate in the transparent scenario. This means that if invoked, an ❀ID[VOI] violation will eliminate the correct transparent output. However, unlike Bedouin Arabic, this selection is motivated by more than a consistent sympathetic preference for coda voicing since it also is the only candidate which obeys the selector. Furthermore, by favoring a failed candidate the selector is at stake in this scenario. Therefore, the SYMPATHY constraint must be invoked and this grammar cannot select the correct outputs for both the transparent and the opaque scenario, as illustrated in (14).

The tableau in (14) also reveals some additional differences between this child grammar and the Bedouin Arabic representation in (12). In the child grammar analysis, the selector and the SYMPATHY constraint are the same, in spite of the IO/OO-FAITHFULNESS distinction. This is also true for the other child opacity scenarios, although the selector is ✯ID[PLACE] and the SYMPATHY constraint is ❀ID[PLACE]. A more prototypical Sympathy analysis, in terms of using ✯ID[PLACE] and ❀ID[PLACE], for the remaining non-ordered counterfeeding scenarios can be seen in the representation of Amahl's productions in (15).

(15) Sympathy tableau for Amahl with ✯ID[PLACE] and ❀ID[PLACE]

/pʌdl̩/	*FRIC	❀ID[PLACE]	*[COR][LAT]	ID[CONT]	✯ID[PLACE]
a ☜❀[pʌdl̩]			*		✓
b →[pʌgl̩]		*!			*
/pʌzl̩/					
a [pʌzl̩]	*!		*		✓
b ☞❀[pʌdl̩]			*	*	✓
c [pʌɣl̩]	*!	*			*
d [pʌgl̩]		*!		*	*

The tableaux in (14) and (15) highlight two additional differences between the child non-ordered counterfeeding representations and the Bedouin Arabic counterfeeding representation. The first is that for the non-ordered counterfeeding scenario, the sympathetic candidate and the correct opaque output are the same. This suggests that Sympathy treats non-ordered counterfeeding similar to transparent process interactions in terms of a self-sympathetic relationship rather than an inter-candidate relationship. While this provides interesting support for a theoretical difference between counterfeeding and non-ordered counterfeeding, it is not necessarily problematic. However, as we saw in (14), the second difference does prove fatal for a Sympathy analysis of non-ordered counterfeeding. Here, the selector constraint favors a candidate which should fail in the transparent scenario. The selector is at stake and this causes an overall failure for this grammar since invoking the SYMPATHY constraint in both scenarios consequently restricts all application of an otherwise legitimate language process, i.e., devoicing.

Thus, like the representations we have seen under standard OT-CC, a Sympathy account of non-ordered opacity fails overall. This failure under a Sympathy representation provides crucial support toward fulfilling an important goal of this chapter. At this point we have seen that neither standard OT-CC nor Sympathy treats non-ordered opacity the same as ordered opacity. Such similarly distinctive treatment of the child opacity data under these two theoretical extensions minimally indicates that non-ordered opacity is not just a by-product of OT-CC formulations. In turn, this supports a larger claim made by this dissertation that non-ordered opacity is a distinct phenomenon in natural language. Moreover, establishing failure of non-ordered opacity under both OT-CC and Sympathy, opacity accounts which diverge on key points, predicts this pattern may also be visible under additional theoretical extensions.[119] Such visibility is expected to be more pronounced under approaches which focus on enforcing a sequential ordering since this is a crucial difference between early child opacity and stable adult opacity.

5.2.2. Local Constraint Conjunction

Constraint Conjunction (Smolensky 1993, 1995) was initially proposed as a way to rule out candidates with multiple violations of otherwise possibly non-fatal MARKEDNESS or FAITHFULNESS constraints. This is achieved through an operation on the constraint set whereby two or more constraints are conjoined to form a separately rankable *derived* constraint. This derived constraint is violated when each of the conjoined component constraints are individually violated by an output candidate. The wide appeal of constraint conjunction comes from a constraint that will rule out a candidate that violates multiple MARKEDNESS or multiple FAITHFULNESS constraints, but allow these constraints to be violated individually. Ranking this constraint above its component constraints therefore creates a type of constraint

[119] This visibility would be expected to manifest as either a failure of non-ordered opacity under additional approaches or a marked contrast with ordered opacity. However, I do not rule out the possibility that modifications to other theoretical extension could allow them to succeed.

conspiracy. The utility of such a powerful constraint quickly led to constraint conjunction becoming a well-established expansion to the theory.

In particular, LCC (Smolensky 1993, 1995, 2006) has been argued to account for many diverse phonological processes in OT literature.[120] These include coda condition (Smolensky 1993; Itô and Mester 1998), sonority hierarchy (Smolensky 1995), accentual phenomena (Alderete 1999), OCP (Alderete 1997; Itô and Mester 1998; but see Kager 1999 for discussion of dissimilation and other OCP applications), cluster restrictions and syllable contact (Baertsch 1998; Baertsch & Davis 2003; Davidson *et al*. 2004), derived environments (Lubowicz 2002; Itô and Mester 2003), vowel harmony (Smolensky 2003; Baković 2000; Itô and Mester 2003), and stages of first language acquisition (Levelt and van de Vijver 1998; Levelt *et al*. 2000). Restricted accumulation of constraint violations within a specific domain also allowed use of conjoined constraints in resolving counterfeeding chain shifts (Kirchner 1996; Moreton and Smolensky 2002). While not equally applicable to all types of opacity, due to its well-developed status in OT, LCC is frequently mentioned as a way to account for this phenomenon in the literature.

While the locus for *locality* can depend on many environmental factors and is difficult to define, it must be restricted for constraint conjunction in order to avoid

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[120] Local Constraint Conjunction was not specifically proposed as a solution to opacity and has always had a larger range of application than opacity-specific approaches such as Sympathy and OT-CC, which have more limited, but still expanding, application beyond opaque interactions.

certain unconstrained results.[121] Smolensky (1993) initially defined *local conjunction* as restricted to a specific domain, as in (16).

(16) The local conjunction of C_1 and C_2 in domain D, C_1 & C_2, is violated iff there is some domain of type D in which both C_1 and C_2 are violated.

An illustration of this restriction on violations comes from Smolensky (1993) where the relevant domain is a coda segment. We can see in (17) that candidate (a) does not violate the locally-conjoined constraint, [*CODA&*PL/LAB]$_{CODA}$, since it violates only one of the conjuncts, *CODA. Candidate (b) violates both conjuncts, *CODA and *PL/LAB, but in different locations, thus satisfying the locally-conjoined constraint. Candidate (c), on the other hand, violates the locally-conjoined constraint because it violates both *CODA and *PL/LAB and the violations are in the same segment.

(17) LCC for coda segments (Smolensky 1993)

VC	*CODA	*PL/LAB	[*CODA&*PL/LAB]$_{CODA}$
a tad.ga	*		
b tad.ba	*	*	
c tab.da	*	*	*

[121] Following Heinz (2007), without restricting constraint conjunction to local constraints, we cannot rule out the saltatory over-fix in Campidanian Sardinian (Bolognesi 1998), where /tɪk/ → [tɪk], but /pag-tɪk/ → /pak-tɪx/. Here, assimilatory voicing of the first /g/ permits /k/ to spirantize. This is the result of changes following a gradually divergent phonetic path, such as /g/ → [k] → [x], where changes to voice and then continuant apply. A locus for locality in Campidanian that would avoid the gratuitous application of spirantization is V *[-cont] V, which would leave /k/ unaffected.

However, this type of locality restriction does not address limitations on the types of constraint domains that can be conjoined under local conjunction or the scope of the domain. Kirchner (1996) tentatively observes that local conjunction could be limited to conjunction of a constraint with itself or with closely related constraints, Lubowicz (2002) proposes that the domain for local conjunction is the smallest domain within which both of the locally conjoined constraints can be evaluated and Moreton and Smolensky (2002) propose that constraints which do not share a *common domain* cannot be conjoined. Heinz (2007) suggests that it is difficult to be completely local for constraint conjunction, but follows Lubowicz (2002) in providing a factorial typology whereby conjoined constraints should not be both marked and unfaithful, i.e., if a constraint is unfaithful, then it should not also be marked, or if a constraint is marked, it should not also be unfaithful. Since MARKEDNESS and FAITHFULNESS fall into two very distinct domains, minimally it should not be possible for a conjoined constraint to assign violations based on both.

However, separate domain restrictions for conjoined constraints may need to be much more specific than the broad scope of MARKEDNESS and FAITHFULNESS. Under the framework of Correspondence Theory, as proposed by McCarthy and Prince (1995), certain constraint families inherently cannot share domains, and hence cannot be locally conjoined. Moreton and Smolensky (2002) look at the typological consequences of LCC and examine McCarthy and Prince's claim with DEP and MAX. Although both are FAITHFULNESS constraints, they fall into different constraint families. DEP constraints are violated by a surface segment with no underlying correspondent, while MAX constraints are violated by an underlying segment with no surface correspondent. As a result, no segment can participate in both a DEP and a MAX violation, and the conjunction (DEP&MAX) must be ruled out by LCC. However, the scope of possible domains and the relationship of the constraints themselves are not consistent in the OT literature. Consequently, definitions for domains and locality remain somewhat ambiguous.

5.2.2.1. Over-application failure

In contrast with Sympathy, LCC largely fails for counterbleeding opacity. As discussed above, MARKEDNESS and FAITHFULNESS minimally fall into two very distinct domains/constraint families and it should not be possible for a conjoined constraint to assign violations based on both. However, this type of violation is precisely what is required for the Tiberian Hebrew opacity from chapter 1. In order for this grammar to prefer the correct output [deʃe] over the transparently formed output [deʃ], we would need a conjoined constraint that could assign a violation to [deʃ]. Therefore, one reason for this counterbleeding failure is that such a conjoined constraint may not be possible based on locality and constraint families. We can see in (18) that [deʃ] incurs a single FAITHFULNESS violation and is otherwise a legitimate output for a grammar which permits codas in general, making an additional MARKEDNESS violation appear gratuitous.[122]

[122] Otherwise, a MARKEDNESS constraint such as *CODA could independently rule this form out. The uncertainty of what MARKEDNESS constraint should be used here is indicated by "M?".

(18) Tiberian Hebrew counterbleeding tableau with conjoined constraints

/deʃʔ/	MAX-C&M?	CODA-COND	*COMPLEX	MAX-C	DEP-V
a [deʃʔ]		*!	*		
b ☜[deʃ]	?			*	
c [deʃeʔ]		*!			*
d →[deʃe]				*	*!

In fact, any output that is formed through a strict sequence of processes application should be inherently problematic for LCC.[123] The most challenging problem for counterbleeding opacity under LCC is that it must find a way to force the second change to occur in what appears to be a gratuitous fashion. Minimally, the Tiberian Hebrew scenario would need a conjoined constraint of MAX-C plus a specific MARKEDNESS constraint restricting words ending in an otherwise legitimate coda segment (i.e., /ʃ/). While such a MARKEDNESS constraint could conceivably be ranked sufficiently low in this grammar so it had no other effect, this conjunction of MARKEDNESS and FAITHFULNESS constraints appears to directly violate previously suggested interpretations of locality and constraint families. Furthermore, the existence of this MARKEDNESS constraint is not independently established in either this language or other natural languages. This type of LCC failure is reinforced by Baković (2007), who demonstrates unsatisfactory results under LCC in additional

[123] A similar failure occurs for the interaction between nasal place assimilation and final stop deletion after a homorganic nasal in the Catalan example introduced in chapter 1. The necessary counterbleeding sequence for producing /bɛnk/ → [bɛŋ] (*1st sg. 'sell'*) is *nasal place assimilation,* producing /bɛnk/ → [bɛŋk], followed by *final (homorganic) stop deletion*, producing [bɛŋk] → [bɛŋ].

scenarios of over-application opacity, such as in self-destructive feeding in Turkish, where any type of opacity resolution requires conjoining a FAITHFULNESS constraint with a theoretically questionable MARKEDNESS constraint. Such a limitation for LCC reduces its viability as a broad-scope representation for opaque interactions, although not necessarily its general value to OT.[124]

The failure for LLC with strictly ordered process over-application also extends to simultaneously over-application. We can see that we run into a very similar problem in terms of finding a legitimate conjoined constraint for the non-ordered counterbleeding of Child 1. In the tableau in (19), we would need the conjoined constraint to assign a key violation to [dɔk]. So again, we find ourselves in a situation where we would need an F&M conjunction, but without a clear indication from this grammar regarding an active structural constraint which we would need to conjoin with the single FAITHFULNESS constraint this output violates, ID[VOI].

(19) Early child counterbleeding tableau with conjoined constraints

/dɔg/	ID[VOI]&M?	*C[+VOI]	*V̆C[+VOI]	ID[VOI]	ID[LEN]
a [dɔg]		*!	*		
b [dɔːg]		*!			*
c ☜[dɔk]	?			*	
d →[dɔːk]			*!	*	*

[124] I do not address here how extensive use of constraint conjunction may also lead to unrestricted proliferation of constraint inventories. Conjoined constraints are typically viewed as developing during acquisition and are thus language-specific rather than members of CON. The possibility of unlimited expansion in language specific ways appears contra to the universal nature of constraint inventories under OT. Under such a scenario, individual languages would be distinguished not only by variation in constraint ranking, but also in the types of constraint in their inventory.

5.2.2.2. Under-application success

A more successful LCC representation can be seen with the Bedouin Arabic counterfeeding scenario introduced in chapter 1. Here, a double violation of the FAITHFULNESS constraints IDENT[LOW] and DEP provides the crucial restriction against both changes occurring in a particular domain. The conjoined constraint IDENT[LOW]&DEP appears to tokenly satisfy locality in terms of both components being members of the same domain (FAITHFULNESS).[125] Ranking this conjoined constraint over DEP eliminates [gi.bur] and correctly selects [ga.bur], but does not affect transparent application of vowel raising in open syllables, as shown in (20).

(20) Bedouin Arabic counterfeeding tableau with conjoined constraints

/ka.tab/	ID[LOW]&DEP	*COMPLEX	DEP	**a*CV	ID[LOW]
a [ka.tab]				*!	
b ☞ [ki.tab]					*
/gabr/					
a [gabr]		*!			
b ☞ [ga.bur]			*	*	
c [gi.bur]	*!		*		*

The LCC representation of Bedouin Arabic counterfeeding is similar to that of other under-application opacity patterns, such as non-ordered counterfeeding. In

125 However, an argument similar to that of Moreton and Smolensky (2002) regarding conjunction of DEP and MAX may be applicable here since a single segment should not participate in both violations.

each case of child acquisition opacity discussed in chapters 2, 3 and 4, constraint conjunction of two IDENT[F] constraints can assign the crucial violation for restricting a full chain shift. Furthermore, since these FAITHFULNESS constraints are both from the IDENT family and the violations occur within the same segment, the conjoined constraint appears to satisfy locality in a much more robust way than constraint conjunction in Bedouin Arabic. Again, a representation of Amahl's grammar in (21) is prototypical of a LCC representation for the child opacity discussed in this dissertation since the conjoined constraint ID[CONT]&ID[PLACE] is used in all but Joan's grammar (which uses ID[NAS]&ID[VOI] for similar results).

(21) Constraint Conjunction for ID[CONT] and ID[PLACE] in Amahl's grammar

/pʌdl̩/	ID[CONT]& ID[PLACE]	*FRIC	*[COR][LAT]	ID[CONT]	ID[PLACE]
a [pʌdl̩]			*!		
b ☞[pʌgl̩]					*
/pʌzl̩/					
a [pʌzl̩]		*!	*		
b ☞[pʌdl̩]			*	*	
c [pʌɣl̩]		*!			*
d [pʌgl̩]	*!			*	*

Although the very nature of the success of LCC with this under-application scenario makes it less revealing in terms of showing a distinction between ordered and non-ordered opacity, there is still an important parallel with one aspect of OT-CC. The examples of child under-application opacity in this dissertation restrict

FAITHFULNESS violations to a very narrow locality, that of a single segment. Intuitively, it appears that this limitation of FAITHFULNESS violations for the same segment is merely another representation of the restrictions imposed by the (b)-clause violations of PRECEDENCE constraints. As such, the conjoined FAITHFULNESS violations produce an effect similar to independently ranked (b)-clause constraints. Therefore, the theory behind LCC appears to function as a precursor to the sequential restriction aspect of PRECEDENCE constraints. This makes the failure of LCC with counterbleeding opacity fully expected. We have seen that PRECEDENCE constraints reflect a balance between enforcing and restricting sequential applications, but LCC represents only one half. Counterbleeding opacity is driven by (a)-clause PRECEDENCE violations under OT-CC, which have no counterpart in conjoined restrictions in some domain. Conjoining constraints merely enables restriction of multiple violations and cannot enforce any type of violation ordering.

Ultimately, the theoretical extensions to OT discussed here only partially illuminate certain fundamental differences between early child opacity and mature grammar opacity; however, they do correspond to the OT-CC representations in chapters 2 through 4 in enlightening ways. Based on the failed representation of non-ordered opacity under both Sympathy and standard OT-CC, it does not appear unreasonable to say that additional representations of early child opacity may also reveal theoretical differences between ordered and non-ordered opacity. The non-ordered opacity failure illustrated under OT-CC and Sympathy, along with the its specific type of success under LCC, provides a foundation for how this pattern fits under current theory and how it expands what current theory must account for.

5.3. Modified OT predictions for process interactions

The ways in which phonological processes can interact with one another, and especially the ways in which these interactions can be represented, is a matter of long-standing and on-going debate. Chapter 1 illustrated the motivation for transitioning from describing such interactions as sequential applications to attempting to have them naturally fall out of an OT constraint-ranking grammar. However, as originally conceived, standard OT focused on general language well-formedness rather than alternation. As a result, the types of process interactions an OT grammar is capable of predicting (and therefore capable of analyzing) is highly dependent on addition of theoretical expansions. This section provides an overview of how specific forms of OT can predict particular process interactions.

5.3.1. Transparent interactions under standard OT

In general, since standard OT fails to represent opaque interactions such as counterfeeding and counterbleeding, it also makes no predictions regarding their existence/occurrence. However, the nature of a constraint ranking domination, where a lower ranked constraint is violated in order to satisfy a higher ranked constraint does specifically predict the occurrence of transparent interactions such as bleeding and feeding. Furthermore, the way in which these interactions are accounted for under OT suggests degrees of inherent markedness since greater complexity of representation is expected to correspond with greater markedness.

Recall the standard OT representation of the Alsatian German bleeding interaction (Kiparsky 1968) introduced in chapter 1. The individual transparent interactions of coda devoicing (i.e., /tag/ → [tak] '*day*') and post-vocalic voiced stop spirantization (i.e., /sagt/ → [saɣt] *3rd sg. 'says'* and /tagə/ → [taɣə] *'days'*) were easily represented by individual MARKEDNESS over FAITHFULNESS rankings: specifically, *CODA[VOI] » ID[VOI] for devoicing and SPIR » ID[CONT] for spirantization. The standard OT representation is for the bleeding scenario repeated here as (22).

(22) Constraint ranking for bleeding interaction in Alsatian German

/tag/	*CODA[VOI]	SPIR	DEP	ID[VOI]	ID[CONT]
a [tag]	*!	*			
b ☞ [tak]				*	
c [taɣ]	*!				*
d [tax]				*	*!
e [tagə]		*	*!		

We can see that a bleeding interaction between these two processes, where coda devoicing bleeds spirantization, is a result of more elaborate constraint interaction than simply MARKEDNESS » FAITHFULNESS. For input /tag/, application of *CODA[VOI] first produces [tak] while application of SPIR first produces *[taɣ]. However, application of both processes would result in the feeding interaction /tag/ → [taɣ] → [tax] found in Low German dialects (Lee 2009). *CODA[VOI] and SPIR like this output equally well, but it violates more FAITHFULNESS constraints than another output these constraints like equally well, [tak]. *[tax] is also harmonically bound by [tak]. Thus, this set of constraints interacts covertly (i.e., a type of constraint conspiracy) to select the correct output without requiring process order stipulations.

A feeding interaction is even more straightforward under a constraint ranking analysis since it is a direct result of MARKEDNESS » FAITHFULNESS rankings. In a feeding scenario, the optimal candidate is simply the one which satisfies all the higher ranked constraints, regardless of violating the lower ranked constraints. This can be seen in the standard OT representation of the Finnish feeding interaction (Kiparsky 1968) introduced in chapter 1 and repeated here as (23).

(23) Ranking favoring feeding interaction between diphthongization and deletion

/teɣe/	*VCV	*HIATUS-RAISING	MAX-V	ID[HIGH]	MAX-C
a [teɣe]	*!				
b [tee]		*!			*
c ☞ [tie]				*	*
d [teɣ]			*!		

Intervocalic consonant deletion (i.e., /teɣe/ → [tee]) is represented by * VCV » MAX-C and diphthongization (i.e., [tee] → [tie]) is represented by *HIATUS-RAISING » ID[HIGH]. The FAITHFULNESS ranking of MAX-V » MAX-C only makes final vowel deletion ungrammatical. The constraint ranking in (23) forms a conspiracy only in the sense that a grammatical output requires application of both processes, which happens naturally as /teɣe/ → [tee] → [tie]. Since the input /teɣe/ fatally violates *VCV, deletion must apply. But the resulting output of [tee] also fatally violates *HIATUS-RAISING, which necessitates application of diphthongization. Rather than relying on a specific order to form the most grammatical output, these processes are free to apply in this constraint-ranking grammar whenever the environment allows. Such minimal requirements for specific constraint interaction (i.e., satisfaction of high ranked constraints) correspond to earlier rule-order related observations by Kiparsky (1971) that feeding interactions should have the least marked status.

5.3.2. Restricted opaque interactions under standard OT-CC

We have seen that the inability of standard OT to predict the existence of opaque interactions which do not fall out of a parallel constraint evaluation can be remedied by introducing theoretical extensions intended to represent opaque interactions. As illustrated in §5.2, individual theoretical extensions may make only limited predictions. However, recall from chapter 1 that standard OT-CC successfully represented both counterfeeding and counterbleeding. The scope of OT-CC representations contrasts with the Sympathy and LCC analyses in §5.2, which were essentially successful with one or the other, but at least not fully with both.

The way OT-CC succeeds with counterbleeding and counterfeeding, i.e., the specific clausal violations under OT-CC, lends itself naturally to classifying under-application and over-application opacity patterns and in making typological predictions regarding these patterns. In general, the MARKEDNESS and FAITHFULNESS constraint violations for counterfeeding and counterbleeding opacity indicate that counterbleeding opacity could be considered more marked since the opaque forms are harmonically bound by the transparent forms (Ettlinger 2008), making it impossible for this form to win under a parallel evaluation. Furthermore, there is a greater incurrence of violations for the opaque forms which appear to be gratuitous violations of FAITHFULNESS constraints. By contrast, the violations for the opaque forms with counterfeeding opacity are neither harmonically bound by the violations for the transparent form nor do they appear to occur gratuitously.

The constraint-violation based relative markedness of counterbleeding versus counterfeeding opacity under standard OT is of course carried into OT-CC and reinforced by the nature of PRECEDENCE constraint violation assignments. We saw in chapter 1 that the ranking of the PRECEDENCE constraint (a) and (b)-clause violation assignments for OT-CC essentially determines whether some type of sequential ordering is permitted, or restricted in a given language. For counterbleeding opacity, the PRECEDENCE constraint violations must force a necessary ordering for FAITHFULNESS violations. However, for counterfeeding opacity, the PRECEDENCE constraint violations need only restrict the possible sequences of orderings for the FAITHFULNESS violations. The ability to enforce or restrict sequential application also appear to lend itself to making predictions regarding the frequency in which such patterns could occur in natural language. It seems reasonable to claim that interactions which merely restrict certain sequential applications are less marked under a parallel evaluation than ones which specifically enforce them. It would then follow that these interactions are predicted to occur more frequently. Thus, OT-CC's ability to highlight differences between patterns of opacity through specific PRECEDENCE constraint violation assignment also appears to allow it to predict that counterfeeding opacity would occur more frequently in natural language than counterbleeding opacity. Such predictions correspond to tentatively observed relative frequencies of counterfeeding and counterbleeding patterns since counterfeeding appears to occur more than twice as often as counterbleeding.[126]

However, we have previously established that the ability to predict opaque interactions in general is not inherent in all theoretical extensions. Particularly so since not all theoretical extensions enjoy equal success with both under-and over-application opacity. Overall, greater focus for opacity representations is given to the ultimately more problematic pattern of counterbleeding. By their very nature extensions which focus on counterbleeding are expected to predict the existence of such patterns, but not to make equal predications for other patterns. Furthermore, extensions that focus on counterbleeding, such as Sympathy (McCarthy 1999), reveal that the cost of success with counterbleeding may be over-restrictiveness in accounts of the less problematic counterfeeding pattern.[127] Similarly, the success of an approach such as LCC with counterfeeding fails to make any type of predictions

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[126] This broad claim is based on the general literature survey of unique occurrences of counterfeeding and counterbleeding opacity scenarios in opacity related literature mentioned in chapter 1. It is part of an on-going attempt to establish a more complete typology of the types of opaque interactions.

[127] Turbidity Theory (Goldrick and Smolensky 1999; Goldrick 2001) similarly focuses on counterbleeding opacity, which leads to potentially problematic representation of some counterfeeding scenarios, particularly for potential chain shifts on the same segment.

regarding counterbleeding interactions. Therefore, while theoretical extensions can certainly enhance standard OT with the ability to make predictions regarding patterns of opacity, the ability to predict under- or over-application in general, and especially more specific forms of opacity, is highly dependent on the focus of a particular theoretical extension.

We have also seen that counterfeeding and counterbleeding are far from the only attested patterns of opacity. Although chapter 1 demonstrates successful OT-CC representation for these patterns, application of OT-CC to less well-known types of opacity is limited in the literature. In Waybright (forthcoming) I show that an OT-CC analysis of other forms of over-application opacity reveals that its success extends beyond counterfeeding and counterbleeding. Baković (2007) identifies a feeding interaction over-application pattern in Turkish that he terms *self-destructive feeding*. Such a pattern is distinct from counterbleeding in that a reverse application (i.e., an unattested Turkish ordering) does not result in a bleeding interaction. This pattern is further distinguished under a standard OT analysis in that self-destructive feeding violates only one significant MARKEDNESS constraint, not both as in the Bedouin Arabic counterbleeding scenario. However, I show that it shares a similar pattern of PRECEDENCE constraint violations and rankings as counterbleeding opacity. Nearly identical OT-CC treatment for both counterbleeding and self-destructive feeding further illustrates the way this extension can be used in classifying distinct forms of opacity under larger primary patterns (i.e., over-application). Furthermore, successful OT-CC representations of patterns of opacity other than counterfeeding and counterbleeding favorably contrasts with the more specific (i.e., limited) opacity applications of other theoretical extensions.

5.3.3. Extended opaque interactions under modified OT-CC

At this point, we have seen that standard OT accounts for, and therefore predicts, transparent interactions such as feeding and bleeding. OT-CC complements standard OT by adding the ability to both account for, and predict, at least a restricted range of opaque interactions. In fact, we have seen that OT-CC's ability to predict opaque interactions is deliberately curtailed in order to rule out process interactions which are predicted not to occur in natural language. However, as illustrated by the child acquisition opacity in chapter 2 through 4, this leaves a theoretical gap. The specific formulations of standard OT-CC appear to be too restrictive to represent the type of opacity that emerges during early L1-acquisition stages. The modified version of OT-CC discussed in this dissertation (i.e., separately rankable PRECEDENCE constraint clauses and lifted metaconstraint) appears to fill in the remaining gap in predicting possible process interactions for natural language.

Although the existence of such a gap is minimally established by the non-ordered opaque interactions seen in early child acquisition (Velten 1943; Ettlinger 2009; Smith 1973; Cho and Lee 2003; Barlow and Keare 2008), the possibility of stable natural language evidence supporting additional aspects of this gap is certainly viable with potential evidence of mutual counterbleeding interactions in Ballard (1971) and Bliese (1975) and potential evidence of a mutual counterfeeding interaction in Hindi-Urdu (Narang and Becker 1971). (See Wolf 2011 for details, as well as a demonstration of how lifting the OT-CC metaconstraint ranking can successfully account for non-derived environment blocking (NDEB: Kenstowicz and Kisseberth 1970; Kiparsky 1973; Wolf 2008)). While evidence of mature grammar opacity requiring either splitting PRECEDENCE constraints or lifting the metaconstraint remains largely inconclusive, it minimally indicates that the extent of possible opacity typologies is not yet fully defined. As such it is at least not inconsistent with the predications in this dissertation for unordered opacity occurring at early stages of L1 development.

An overview of the revised Optimality Theoretic process interaction predictions discussed in this section is given in Figure **4**. This depiction illustrates the cumulative nature of these predictions since each successive modification enhances the ability of the theory to represent additional forms of process interaction. However, this representation remains somewhat over-simplified in terms of the types of interactions each level of the theory permits. We have seen that even the brief overview of opaque interactions in chapter 1 is sufficient to establish that Figure **4** is only a partial view of the possible process interactions, opaque or otherwise, permitted at each level.[128]

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[128] This list, while by no means comprehensive, included opaque feeding (Lee 2007), mutual bleeding (Itô and Mester 2003), obligatory counterbleeding (Wolf 2008; Ettlinger 2008), as well as self-destructive feeding, nongratuitous feeding and cross-derivational feeding (Baković 2007).

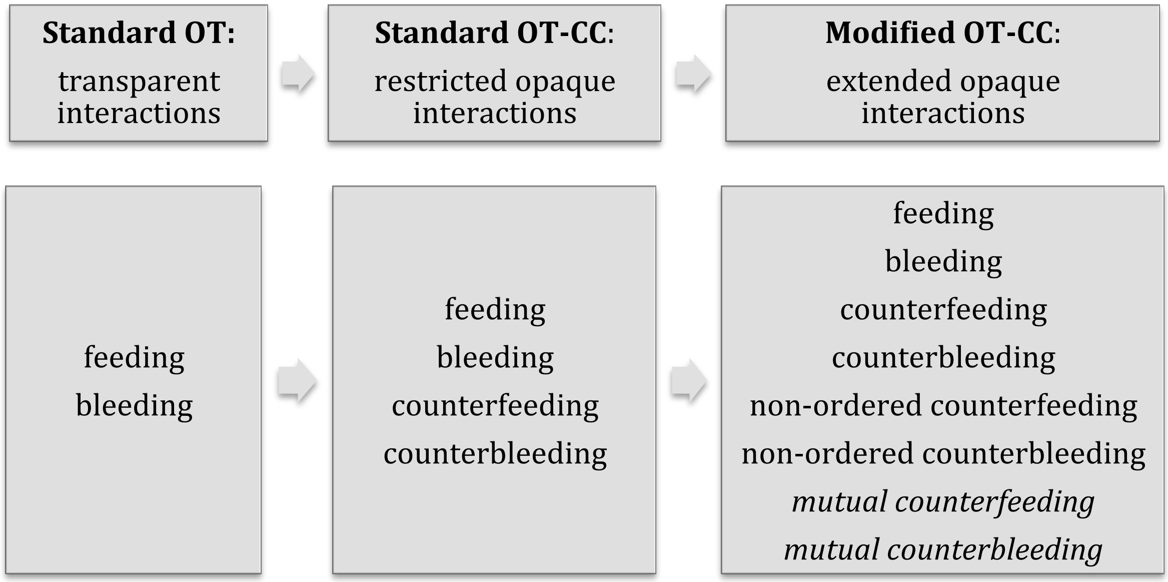

Figure 4: Overview of Optimality Theoretic process interaction predictions

While this current study allows us to minimally establish the revised Optimality Theoretic predictions in Figure **4**, the nature of these additional opaque interactions under OT-CC is developed more fully in Waybright (forthcoming).

5.4. Conclusion

This chapter has provided a broader view of how non-ordered opacity fits into the historic and ongoing problem that opacity generates for Optimality Theory. Specifically, it shows how not only standard OT fails to predict it, but theoretical extensions which account for opacity also fail to predict it without non-trivial modifications. Such modifications necessarily open the door for predictions of a larger range of opaque interactions in natural language. Proposals for these types of patterns are not new (see Wolf 2011), but generally lack explicit evidence. Data from child developmental stages, in spite of its transient nature, crucially provides this support. Moreover, accounting for opaque interactions in these grammars reveals how the initial state itself creates the conditions which allow them.

The findings in this dissertation contribute to our understanding of first language development in multiple ways. Possibly the most significant aspects are insight into a revised initial-state for more mainstream OT and establishing a more robust default constraint class ranking. We saw earlier that an initial-state of MARKEDNESS » FAITHFULNESS provided sufficient explanation for transparent interactions when evaluated in parallel. However, failure of opaque interactions under the same evaluation provides a clear indication that the source of these interactions is insufficiently accounted for by this initial state.

The early emergence of opacity in diary studies such as Velten (1943), Smith (1973), Cho and Lee (2003) and Ettlinger (2009) indicates that it must be at least partially driven by structure in the initial state. However, an initial state of MARKEDNESS » FAITHFULNESS again fails to provide sufficient explanation for the emergence of opaque forms during these early stages. The initial-state driven explanation of non-ordered opacity given in chapter 4 therefore inevitably involves explicit theoretical claims regarding a re-conceptualized initial-state. These revised initial-state representations build upon earlier proposals of MARKEDNESS » FAITHFULNESS, but incorporate constraint classes which can account for opaque interactions, such as PRECEDENCE.

Theoretical extensions to OT which introduce additional constraint classes must account for when and how these constraints enter the grammar. If they are part of CON, then they must be part of the default constraint ranking. We have seen that initial state proposals which address this tend to converge on a representation where the class of output related FAITHFULNESS (i.e., OO-FAITHFULNESS, SYMPATHY, etc.) has a default ranking between MARKEDNESS and IO-FAITHFULNESS. In this dissertation I have argued for a necessary OT-CC initial-state ranking of MARKEDNESS » PRECEDENCE » FAITHFULNESS. We have also seen that non-ordered opacity appears to be limited to early stages of acquisition related constraint re-ranking. This suggests that such a pattern is largely driven by structure in the initial state. An initial state source is further supported by the findings in chapter 3, where both under- and over-application opacity in phonologically delayed L1-acquisition patterns as counterfeeding and counterbleeding rather than non-ordered patterns of opacity. In particular, the contrast between delayed development opacity and the type of opacity that emerges in typically developing children provides crucial evidence that non-ordered opacity is more than just a by-product of L1-acquisiton or even the general process of language acquisition.

In chapter 4 we saw how non-ordered opacity falls out naturally in normal developmental stages stemming from a revised initial-state of MARKEDNESS » PRECEDENCE » FAITHFULNESS. This OT-CC initial-state not only facilitates the conditions for non-ordered opacity, but allows us to make falsifiable predictions regarding its occurrence: a) that it will emerge in a particular stage of early language development, and b) that it will disappear from the grammar once inevitable constraint re-ranking eradicates the conditions required for it to emerge. Following principles of language learnability (Tesar and Smolensky 1998), inevitable L1 constraint re-ranking will pass through an acquisition Stage where the conditions are optimal for this pattern to emerge. Moreover, the same principles of language learnability will also be responsible for the constraint re-ranking that eventually over-writes these conditions. Therefore, including PRECEDENCE constraints ranked between MARKEDNESS and FAITHFULNESS in the OT initial-state not only gives us a way to analyze previously overlooked patterns of opacity, but to also to explain why they emerge at specifically, and only, this point of first language acquisition.

The child acquisition scenarios representations discussed here promote an important reconceptualization of the initial state, as well as provide promising and testable predications for universal stages of L1-acquisition. However, many interesting aspects of this research remain under-developed. In particular I would like to establish a larger cross-section of early L1 opacity in additional languages. The current study looks at English and Korean, but predicts that the initial state will effects all first stages of L1-acquisition in a similar manner. I also anticipate it would be valuable to continue exploring the possible success or failure of early child opacity under additional theoretical extensions since they may reveal additional key contrasts between ordered and non-ordered opacity.

This study assumes that typological frequency for opacity patterns corresponds to particular indications of markedness under theoretical extensions such as OT-CC.

A currently on-going survey seeks to expand upon this by establishing the typological frequencies of not only counterfeeding and counterbleeding, but additional opaque interactions such as opaque feeding (Lee 2007), mutual bleeding (Itô and Mester 2003), obligatory counterbleeding (Wolf 2008; Ettlinger 2008), self-destructive feeding, nongratuitous feeding and cross-derivational feeding (Baković 2007). This survey also looks at a comparative analysis of these opaque interactions under OT-CC. And finally, following existing claims in Wolf (2008, 2011), stable grammar evidence of opaque interactions that require modified OT-CC representations would prompt interesting research into why non-ordered opacity might linger past early acquisition stages.

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[129] Note: The link to the Rutgers Optimality Archive is http://roa.rutgers.edu/.

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Biography

Jill Waybright also holds undergraduate degrees in Mathematics and English Literature, as well as a Master of Arts in Linguistics.