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On the interaction of velar fronting and labial harmony

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Abstract

This article documents the typological occurrence and interactions of two seemingly independent error patterns, namely Velar Fronting and Labial Harmony, in a cross-sectional investigation of the sound systems of 235 children with phonological delays (ages 3;0 to 7;9). The results revealed that the occurrence of Labial Harmony depends on the occurrence of Velar Fronting, and that, when these processes co-occurred, all three predicted types of interactions were attested. A constrained version of Optimality Theory is put forward that offers a unified explanation for the implicational relationship between these error patterns and their observed interactions. The findings are compared with the results from other studies and are considered for their theoretical and clinical implications.

Keywords

typology; implicationally related error patterns; Optimality Theory; phonological delay

Introduction

Children's phonological error patterns are often described as rules or processes that effect changes in a well-defined class of sounds. The problem is that the affected class of sounds can vary for a given process. For example, consider the process of Labial Harmony (e.g. Vihman, 1978; Stoel-Gammon & Stemberger, 1994; Bernhardt & Stemberger, 1998; Pater & Werle, 2003). This process is a particular instance of amore general process of Consonant Harmony, both cause non-adjacent consonants to assimilate in place of articulation. In cases of Labial Harmony, a labial consonant can condition or trigger the process progressively or regressively, and the usual target of assimilation is a coronal consonant (e.g. 'bed' realized as [bɛb]). The vulnerability of coronal consonants as targets of assimilation has, in some accounts, been attributed to their being unmarked and underspecified for place of articulation (e.g. Stoel-Gammon & Stemberger, 1994). However, Labial Harmony sometimes targets velar consonants, changing them to labials (e.g. 'bag' realized as [bæb]). The marked character of velars poses a problem for underspecification accounts because they predict that, while velars are viable triggers of assimilation, they would be unlikely targets of such a process. Adding to this problem is the fact that a given child might allow coronals to undergo assimilation in some words, while also allowing coronals to occur in that same context in other words, thereby resulting in apparent exceptions to Labial

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Harmony (e.g. ‘bed’ realized as [bɛb], but ‘bag’ realized as [bæd]). In this latter case, the coronal exceptions to Labial Harmony correspond with target velars, implicating another common process, namely Velar Fronting (e.g. Grunwell, 1982; Ingram, 1989; Smit, 1993; Inkelas & Rose, 2007; McAllister, 2010). Velar Fronting is a non-assimilatory neutralization process that merges the place distinction between coronals and velars in favour of coronals in one or more contexts. In rule-based Generative Phonology, these apparent exceptions to Labial Harmony would be accounted for by ordering Velar Fronting after Labial Harmony in a counterfeeding relation (e.g. Dinnsen, Barlow, & Morrisette, 1997). The potential for an interaction between these two processes offers a possible direction for explaining why Labial Harmony might sometimes target coronals and/or velars. That is, the different targets of Labial Harmony may be a consequence of different predictable interactions with Velar Fronting. In pursuit of such an explanation, it is necessary to answer at least two questions of theoretical and clinical significance: (1) Are the processes of Labial Harmony and Velar Fronting truly independent and (2) are these processes free to interact in all logically possible ways?

If Velar Fronting and Labial Harmony were independent, there would be several different typological expectations, namely that neither process would occur, that either one could occur without the other or that the two processes could co-occur. Those predictions are spelled out in (1).

(1) Predictions about independent processes

(a) Neither Velar Fronting nor Labial Harmony (e.g. ‘bed’ [bɛd], ‘bag’ [bæg])

(b) Velar Fronting without Labial Harmony (e.g. ‘bed’ [bɛd], ‘bag’ [bæd])

(c) Labial Harmony without Velar Fronting (e.g. ‘bed’ [bɛb], ‘bag’ [bæg])

(d) Velar Fronting and Labial Harmony co-occur (see different interaction effects in (2))

The co-occurrence of Velar Fronting and Labial Harmony in a child’s phonology should have the further consequence of producing any one of the three interaction effects, as sketched in (2). In rule ordering terms, one potential effect would follow from ordering Velar Fronting before Labial Harmony in a feeding relation (2a). The coronal output of Velar Fronting would serve as an appropriate input to Labial Harmony, triggering its application as well. The consequence of such an interaction is that target coronals and velars would both undergo Labial Harmony. Feeding interactions for other processes in both fully developed and developing phonologies are well documented and are presumed to represent an unmarked interaction (e.g. Kiparsky, 1965; Dinnsen, Gierut, Morrisette, Green, & Farris-Trimble, 2010b).

The reverse ordering of these processes would yield a counterfeeding interaction (2b). The effect of such an interaction is that target coronals would undergo Labial Harmony, but coronals derived from Velar Fronting would be immune to Labial Harmony. Counterfeeding interactions for other processes are also quite common in fully developed and developing systems, although they are considered more marked than feeding interactions (e.g. McCarthy, 2002; Dinnsen, 2008c).

The third potential type of interaction involves something more than rule ordering and has been dubbed a ‘grandfather effect’ in the recent optimality theoretic literature (e.g. McCarthy, 2002). Such effects are also known as ‘non-derived environment blocking’ in the rule-based framework of Lexical Phonology (e.g. Kiparsky, 1982). For example, the Velar Softening process of adult English is constrained to apply exclusively in derived environments (e.g. /k/ alternates with /s/ in ‘electri[k]~electri[s]ity’, but /k/ does not

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alternate in non-derived forms like '[k]itty'). Grandfather effects involving other processes are a common phenomenon in fully developed languages and have also begun to come to light in young children's developing phonologies (e.g. Barlow, 2007; Dinnsen, 2008c; Dinnsen & Farris-Trimble, 2008c; Dinnsen et al., 2010b). The consequence of a grandfather effect in this instance would be that target coronals would be immune to Labial Harmony, and only those coronals derived from Velar Fronting would undergo Labial Harmony (2c).

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(2) Predictions about interactions between processes
(a) Feeding (e.g. 'bed' [bɛb], 'bag' [bæb])
(b) Counterfeeding (e.g. 'bed' [bɛb], 'bag' [bæd])
(c) Grandfather effect (e.g. 'bed' [bɛd], 'bag' [bæb])
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To our knowledge, there has been no systematic attempt to establish the facts associated with these two error patterns or to evaluate their typological predictions as a possible explanation for the different targets of Labial Harmony. This represents a significant gap in the literature because any prospective findings bear on fundamental theoretical and clinical issues. On the theoretical side, the need to arrive at a theory that fits with the facts of language demands that we determine whether these two error patterns are indeed independent and whether they interact to their full potential. After all, not all processes are independent; some processes do depend on others (e.g. Prince & Smolensky, 1993/2004; Dinnsen & O'Connor, 2001). Additionally, some processes have been found to interact with one another in more limited ways (e.g. Dinnsen, Green, Gierut, & Morrisette, in press). On the clinical front, it is also important to arrive at the proper characterization of interacting error patterns, especially because some interactions have been shown to pose special challenges for remediation (e.g. Gierut, 1986; Dinnsen, 2008b; Morrisette & Gierut, 2008). Some of those more problematic interactions have involved breaking up chain shifts and splitting allophones of one phoneme into two separate phonemes. Establishing the relationship, if any, between Labial Harmony and Velar Fronting should, at the very least, help in the assessment of the problem and the selection of treatment targets.

In an effort to fill this gap, cross-sectional evidence from children with phonological delays (age 3;0 to 7;9) is presented here regarding the typological occurrence and interaction of Velar Fronting and Labial Harmony. It will be argued that Labial Harmony is not an independent process, but rather that its occurrence depends on the occurrence of Velar Fronting. We will further establish that these two error patterns interact to their full potential. An optimality theoretic account of these facts is then put forward that employs both a fixed ranking among certain constraints (e.g. Prince & Smolensky, 1993/2004) and an enriched set of markedness constraints, specifically comparative markedness constraints (e.g. McCarthy, 2002). These findings are also shown to differ from those of other interacting error patterns, both in terms of their typological characteristics and their clinical implications.

Participants and methods

Participants

The children who participated in this study were typically developing in all respects, except for evidence of a phonological delay. They scored within normal limits on all standardized tests of hearing, non-verbal intelligence, oral-motor structure and function, receptive vocabulary and expressive and receptive language (for details, see Gierut, 2008). However, all children also scored at or below the 5th percentile on the *Goldman-Fristoe Test of Articulation* (Goldman & Fristoe, 1986). This means that 95% of other children of the same age and gender as these participants had phonological systems that were more in keeping with the target phonology. Children with phonological delays were selected for study because they can offer a special window onto early phonological development. That is, the phonologies of children with phonological delays tend to resemble those of younger children with typical phonological development. However, many of the research challenges that arise in working with younger children are avoided with older children (Ferguson & Farwell, 1975). For example, because younger children have shorter attention spans and limited understanding of structured elicitation tasks, it is often difficult to secure the type and amount of data needed to motivate phonological claims; older children with phonological delays do not present this same challenge.

The data were drawn from the Developmental Phonology Archive of the Learnability Project at Indiana University (Gierut, 2008). The Archive includes an exhaustive compilation of data on the productive phonological development of 235 children. Moreover, the data were collected in a systematic, uniform manner, facilitating comparisons within and across children and over time. This study limited itself to the pretreatment phonologies of these children to avoid any influence of clinical intervention. All claims about the children's phonologies are based on a comprehensive speech sample and standard phonological analysis procedures (Gierut, 2008). The speech sample for each child was elicited in a spontaneous picture-naming task and was audio recorded. The pictures related to a probe list of 544 words familiar to children of that age (Gilhooly & Logie, 1980a, b; Bird, Franklin, & Howard, 2001), which sampled the full range of English consonants in initial, medial and final positions in multiple exemplars. The audio-recorded sessions were phonetically transcribed on the basis of impressionistic judgements by trained listeners with considerable experience in the transcription of clinical populations. For transcription reliability purposes, 10% of all probes were retranscribed by an independent judge. The overall transcription reliability measure was 92% agreement for all phonologies, which is within the range of what is typically deemed acceptable (e.g. Shriberg & Lof, 1991).

Analysis procedures

The pretreatment phonological records of all 235 children in the Archive were examined to determine the extent to which the typology in (1) and (2) was instantiated. For the purposes of our analysis, the larger probe list of 544 words included 34 words in which Velar Fronting alone would be expected to apply, 24 words in which Labial Harmony alone could potentially apply and another 31 words in which both Velar Fronting and Labial Harmony were potentially applicable. To properly evaluate the predictions of the typology, all children had to have at least a labial consonant in their phonemic inventories in order to be considered. The reason behind this condition was that labial consonants were both potential triggers and potential products of Labial Harmony. This had the consequence of setting aside six children whose pretreatment inventories excluded labial consonants. These latter cases would have no probative value in judging the independence of the two processes. This requirement left us with 229 children, who were then entered into the more focused analysis.

To identify a process as active in a child's phonology, we adopted the operational definition employed in other studies that active processes were those that affected at least 25% of relevant words with a specific substitution pattern (e.g. McReynolds & Elbert, 1981; Dinnsen et al., 2010b; Dinnsen, Gierut, & Farris-Trimble, 2010a; Dinnsen et al., in press). One reason for accepting a value as low as 25% is that it would be generous in identifying an interaction, if one were to occur. This is important because, as we will show, even this generous criterion failed to identify a particular typological prediction. There is also some value in not accepting a lower criterion level because so few words would be affected, making it difficult to differentiate random errors from those that are systematic. We could have adopted the slightly lower 20% criterion employed by Pater and Werle (2003), but it would have only increased the number of active processes without changing the typology. We will see that our 25% criterion was, nonetheless, sufficient to capture variation in the occurrence of different interaction types within a given phonology (see especially Child 18 below). To further clarify the implementation of this criterion, if target velars were produced as a coronal in 25% or more of the relevant words, Velar Fronting was considered active. However, target appropriate realizations or any substitutes other than a coronal for target velars, such as null or a consonant with some other place or manner of articulation, were not counted as evidence of Velar Fronting. The rationale for excluding these alternative substitution patterns is that their outputs could not interact with Labial Harmony in any of the ways relevant to the evaluation of the typology in (1) or (2). The same strict criterion was applied to Labial Harmony. That is, a target coronal had to be realized as a labial when a labial trigger occurred elsewhere within the word to count as an instance of Labial Harmony.

To establish a counter feeding interaction between Labial Harmony and Velar Fronting, it was necessary for the two processes to co-occur in a given phonology with each process meeting the minimum 25% occurrence criterion. To identify a feeding interaction or a grandfather effect, certain other inferences were necessary because the output of Velar Fronting would immediately be subject to Labial Harmony, resulting in a labial consonant as the observed output. Consequently, it was assumed that Velar Fronting and Labial Harmony were both active if at least 25% of the target velar words were realized with a labial consonant as the substitute when a labial consonant immediately preceded or followed within the word. This latter assumption is necessary within rule-based derivational accounts because the output of Velar Fronting must be hypothesized as an intermediate step in a derivation and would, thus, not be directly observable in a putative feeding interaction or a grandfather effect. This is not an issue in Optimality Theory, and, thus, no special inferences are necessary regarding the activity of these processes for feeding interactions or grandfather effects because the evaluation of output candidates is conducted in parallel. Note that these interactions would, in any case, be supported by the independently established activity of Velar Fronting in non-harmonizing contexts.

For analysis reliability purposes, 10% of the 229 children's phonologies were randomly selected for reanalysis by an independent judge. The reanalyses concurred with the original analyses with 99.8% agreement.

Results

Independence of processes

With regard to the typological predictions in (1) and from the available set of 229 children, our analysis procedures identified 121 children (53%) who failed to exhibit either Velar Fronting or Labial Harmony as active processes, complying with the prediction in (1a). This means that none of the 121 children met the 25% occurrence criterion for either process. They either produced the relevant target sounds correctly or in error because of some other process, or their Velar Fronting and Labial Harmony errors fell well below the 25% threshold criterion. More specifically, Velar Fronting was judged to be inactive for this group of children because it affected on average only 5% of the relevant words (SD = 5%; range 0–24%). The mean age of this group was 4;4 (SD = 10 months; range 3;0 to 7;9); 225 of the 229 children fell below the 25% criterion for Labial Harmony. For this group of children, Labial Harmony affected, on average, fewer than 1%of the relevant words (SD = 3%; range 0–22%). The mean age of these children was 4;5 (SD = 10 months; range 3;0 to 7;9).

A total of 108 of the 229 children (47%) exhibited an active Velar Fronting process. The active character of Velar Fronting is supported by the fact that it affected, on average, 65% of the relevant words (SD = 28%; range 26–100%). The mean age of this group was 4;5 (SD = 10 months; range 3;0 to 7;4). The data in (3) are from Child 224 (age 4;7) and are illustrative of the cases in this latter category. Note in (3a) that velars were replaced by coronals, but Labial Harmony did not operate on target coronals (3b) or on coronals derived from Velar Fronting (3c). For 11 of the children in this category, 100% of the relevant words were affected by Velar Fronting. Words not affected by Velar Fronting were either produced correctly or produced in error by unrelated processes such as Deletion, Spirantization or Glottal Stop Replacement. A total of 104 of these children complied with the specific prediction that Velar Fronting should be able to occur without Labial Harmony (1b).

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(3) Child 224 (age 4;7)
(a) Target velars underwent Velar Fronting
[toʊt] ‘coat’ [dʌti] ‘duckie’
[tætʊ] ‘cracker’ [deɪt] ‘gate’
(b) Target coronals resisted Labial Harmony
[bɛd] ‘bed’ [mun] ‘moon’
[mʌni] ‘money’ [bateɪdoʊ] ‘potato’
(c) Derived coronals resisted Labial Harmony
[bæt] ‘back’ [bædi] ‘baggie’
[tʌp] ‘cup’ [pɪdi] ‘piggy’
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Four of the 229 children (~2%) exhibited Labial Harmony. On average, Labial Harmony affected 28%of the relevant words (SD = 4%; range 25–33%). The mean age of this group was 3;11 (SD = 5 months; range 3;4 to 4;4). The relatively small percentage of words affected by this process may be indicative of a process that is near suppression and/or one that is dependent on some other process. Importantly, all four of these children also exhibited Velar Fronting (~4% of the 108 children with Velar Fronting). The co-occurrence of these two processes means that they also have the potential to interact with one another in any one of three ways to be documented below. Although these four children instantiate the prediction that the two processes should be able to co-occur (1d), the typological prediction that Labial Harmony should be able to occur without Velar Fronting (1c) was not supported. The significance of this asymmetry will be taken up in our optimality theoretic account and in the discussion.

Although the percentage of children evidencing Labial Harmony was relatively small compared with that of Velar Fronting, the significant typological fact is its implicational relationship with Velar Fronting. It must also be kept in mind that early developing phonologies can exhibit a wide variety of error patterns, and the likelihood of any two specific error patterns co-occurring with the potential to interact is inherently small, but typologically important. For example, in comparable studies of children with phonological disorders, the two error patterns of Deaffrication and Velar Harmony and the two other error patterns of Labialization and Dentalization have been shown to co-occur and interact in 7–8% of these children’s sound systems (e.g. Dinnsen et al., 2010a,b; Dinnsen et al., in press). Contributing to the small numbers is the fact that the occurrence of some error patterns can preclude the occurrence of others. For example, a process such as Labial Harmony could be bled by some other process that either deleted or replaced those coronal targets or labial triggers with some other sound such as a glottal stop.

Attested interactions of processes

Turning to the typological predictions in (2) and those four children who evidenced the co-occurrence of Velar Fronting and Labial Harmony, it was found that all three of the logically possible interactions were attested. Representative cases are presented below for each of the observed interactions.

Child 18 (age 3;4) exhibited both a feeding interaction and a counterfeeding interaction between Velar Fronting and Labial Harmony at the pretreatment point in time, as illustrated in (4). Given our 25% occurrence criterion for claiming that a process was active, it was possible to identify both interaction types at a single point in time. That is, a feeding interaction was observed because Velar Fronting was active (4b), and at least 25% of the target coronals and another 25% of target velars underwent Labial Harmony (4a) and (4c), respectively. A counterfeeding interaction was also observed because Velar Fronting was active (4b), and at least 25% of target coronals underwent Labial Harmony, whereas another 25% of the target velars underwent Velar Fronting without undergoing Labial Harmony (4a) and (4d), respectively.

(4) Child 18 (age 3;4)

(a) Target coronals underwent Labial Harmony

[bæbi] ‘money’ [bubi] ‘bootie’

[bʌbɪʔ] ‘button’ [bʌbi] ‘tub-i’

(b) Target velars underwent Velar Fronting

[doʊʔ] ‘coat’ [dɪɾi] ‘ziggy’

[deɪjɔ̃] ‘crayon’ [deɪt] ‘gate’

(c) Velar Fronting fed Labial Harmony

[bɪbi] ‘piggy’ [bɔʔbɔʔ] ‘pocket’

[v̥æv̥um] ‘vacuum’ [bæbi] ‘baggie’

(d) Velar Fronting counterfed Labial Harmony

[dɔbi] ‘cob-i’ [duʔdi] ‘goofy’

[doʊmbi] ‘comb-i’ [dɪː] ‘glove’

The theoretical significance of the two different, co-existing interactions and the variable application of processes will be taken up in the discussion.

Child 99 (age 3;10) exhibited a counterfeeding interaction between these two processes as illustrated in (5). Unlike Child 18, there was no concurrent evidence of a feeding interaction. The forms in (5a) show that intervocalic coronals were produced in error, being replaced by a labial glide when a labial consonant occurred earlier in the word, presumably because of Labial Harmony. Interestingly, intervocalic coronals were replaced by a placeless glottal stop or by a palatal glide when there was no labial trigger in the word (5b). These facts suggest that the onset timing slot of intervocalic coronals was preserved (i.e. no Deletion) and that place features were not licensed intervocalically, unless by assimilation, as might follow from Labial Harmony. The forms in (5c) illustrate the independent application of Velar Fronting. Finally the forms in (5d) show that coronals derived from Velar Fronting were exempted from Labial Harmony, as would follow from a counterfeeding interaction.

(5) Child 99 (age 3;10)

(a) Target coronals underwent Labial Harmony

[muwi] ‘moon-i’ [bʌwɪn] ‘button’

[buwi] ‘bootie’ [pwæwoʊ] ‘piano’

(b) Intervocalic coronals replaced by glottal stops or palatal glides in non-harmonizing contexts

[tʌʔin] ‘cutting’ [iʔin] ‘eating’

[aɪʔi] ‘icy’ [teɪjoʊ] ‘potato’

(c) Target velars underwent Velar Fronting

[dʌː] ‘gun’ [dʊrə] ‘girl’

[toʊː] ‘coat’ [tɪʔɪn] ‘kitchen’

(d) Velar Fronting counterfed Labial Harmony

[pɪd] ‘pig’ [dʌm] ‘gum’

[toʊm] ‘comb’ [tɔp] ‘cough’

Rounding out the logically possible interactions, a grandfather effect was evidenced by two of the four children, Child 141 (age 4;0) and Child 192 (age 4;4). Inasmuch as the children’s realizations were essentially the same, illustrative data from Child 192 alone are given in (6). With a grandfather effect, the expectation was that fewer than 25% of the target coronals in an assimilatory context would undergo Labial Harmony (6a). The further expectation was that Velar Fronting would be active (6b), and at least 25% of the target velars in an assimilatory context would undergo Labial Harmony (6c).

(6) Child 192 (age 4;4)

(a) Target coronals resisted Labial Harmony

[beɪdi] ‘bed-i’ [mʌni] ‘money’

[peɪn] ‘paint’ [buʔ] ‘boot’

(b) Target velars underwent Velar Fronting

[tatə] ‘cracker’ [dʊ] ‘girl’

[doʊʔ] ‘goat’ [teɪ] ‘catch’

(c) Target velars underwent Velar Fronting and Labial Harmony

[pipi] ‘piggy’ [paʔpa] ‘pocket’

[bæʔmæʔ] ‘vacuum’ [peɪpi] ‘picture’

By way of summary, the main findings from this study that call out for a theoretical account are the following: First, the two error patterns of Velar Fronting and Labial Harmony do not appear to be independent of one another. That is, the occurrence of Labial Harmony depends on the occurrence of Velar Fronting. Velar Fronting can occur on its own or not at all, but Labial Harmony can occur if and only if Velar Fronting also occurs. Related to this point is the fact that the two processes can also co-occur. Such a typology is indicative of an implicational relationship between the two processes. The second main finding is that, when the two processes co-occur, they can and do interact to their full potential, that is, in either a feeding relation, a counterfeeding interaction or a grandfather effect. The combined effect of the implicational relationship between these two processes and their various interactions explains why Labial Harmony sometimes operates on both target coronals and velars (feeding), or on target coronals alone (counterfeeding) or on target velars alone (grandfather effect). A theoretical framework that is well suited to the characterization of implicational relationships and various interactions between processes is a version of Optimality Theory that allows fixed rankings among certain constraints while also providing for freely permutable rankings among certain other constraints (e.g. Prince & Smolensky, 1993/2004; McCarthy, 2002). In what follows, we formulate an optimality theoretic account of the attested typology.

Optimality theoretic account

The processes of Velar Fronting and Labial Harmony both involve changes in place features, and both thus require the dominance of markedness constraints (*Dorsal and Agree, respectively) over a generalized antagonistic faithfulness constraint (Faith) to compel the change. Such a ranking means that it is more important to comply with the markedness constraints than it is to be faithful to the input. The constraints relevant to these processes are given in (7) and will be described in more detail as we develop the account.

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(7) Constraints
(a) Conventional markedness
*Dorsal: Dorsal consonants are banned
*Labial: Labial consonants are banned
Agree: Multiple consonants with different place features are banned within a
word
(b) Comparative markedness
OAgree: Multiple consonants within a word that differ in place of
articulation and that are shared with the Fully Faithful Candidate (FFC) are
banned
NAgree: Multiple consonants within a word that differ in place of
articulation and that are not shared with the FFC are banned
(c) Faithfulness
Faith: Corresponding input and output segments must be identical
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Let us consider first the process of Velar Fronting alone. The display in (8) shows the required ranking of constraints with an illustrative tableau for words such as 'key'. The markedness constraint *Dorsal and its undominated character in the hierarchy reflect the typologically marked nature of velars relative to other places of articulation (e.g. Maddieson, 1984; de Lacy, 2006) and is in accord with the default ranking of markedness over faithfulness in the initial state (e.g. Smolensky, 1996). This constraint assigns a fatal violation to the FFC (8a) and eliminates it from the competition. The remaining two candidates contain less marked places of articulation, but each violates the generalized faithfulness constraint Faith because they differ from the input. The choice is then passed down to the next lower ranked constraint, *Labial. The ranking of *Labial below Faith is motivated by several facts: (a) Labials do occur in these children's inventories, (b) they survive to trigger processes such as Labial Harmony and (c) they do not undergo any changes. Faith, thus, protects labial consonants. The lower ranking of *Labial assigns a fatal violation to candidate (8c), eliminating it from the competition and explaining why Velar Fronting results in a coronal (candidate (8b)), rather than a labial. Such effects have been referred to as 'Emergence of the Unmarked' (e.g. McCarthy & Prince, 1994).

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(8) Velar Fronting
Ranking: *Dorsal >> Faith >> *Labial
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‘key’ /ki/	*DORSAL	FAITH	*LABIAL
a. FFC ki	*!		
b. ☞ ti		*	
c. pi		*	*!

To see how Labial Harmony is blocked from occurring in the phonologies of those children with Velar Fronting and no Labial Harmony (e.g. Child 224), we need to consider first the constraint that compels Labial Harmony, namely AGREE, and its ranking in the hierarchy. AGREE is a generalized markedness constraint that disfavours the occurrence of words with multiple consonants differing in their place of articulation. We will see momentarily that this constraint encapsulates two independent and freely permutable comparative markedness constraints, $_{O}$AGREE and $_{N}$AGREE. For the moment, however, it is sufficient to envision AGREE as a unified constraint that would assign a violation to a word with, for example, a labial and a coronal consonant, but two labial consonants in the same word would comply with the constraint. Now consider the tableaux in (9) and (10) for two words such as ‘bed’ and ‘bag’, respectively. Although the FFC (9a) and (10a) in each violates AGREE, the low ranking of that constraint makes the violation less serious. In (9), the assimilated candidate (9b) is eliminated by its violation of FAITH, allowing the FFC (9a) to be selected as optimal. In (10), the FFC (10a) is eliminated by its violation of the undominated constraint *DORSAL. The two remaining candidates each violate FAITH, passing the decision down to *LABIAL. The assimilated candidate (10c) incurs two violations of *LABIAL for its two labial consonants, whereas the unassimilated candidate (10b) incurs just one violation of *LABIAL. Candidate (10b) is thus preferred and selected as the winner even though it incurs a violation of the lower ranked AGREE. If AGREE were ranked in the same stratum with *LABIAL, candidates (10b) and (10c) would tie in the number of violations, predicting free variation in the realization of such words. Ties are, thus, one way of accounting for certain instances of variation; see the discussion section for other approaches to variation.

(9) No Labial Harmony

Ranking: *DORSAL >> FAITH >> *LABIAL >> AGREE

‘bed’ /bɛd/	*DORSAL	FAITH	*LABIAL	AGREE
a. FFC ☞ bɛd			*	*
b. bɛb		*!	**	

(10) Velar Fronting without Labial Harmony

‘bag’ /bæg/	*DORSAL	FAITH	*LABIAL	AGREE
a. FFC bæg	*!		*	*
b. ☞ bæd		*	*	*
c. bæb		*	**!	

Turning to the account for a feeding interaction between Velar Fronting and Labial Harmony (e.g. Child 18), consider the constraint hierarchy and tableaux for words such as ‘bed’ and ‘bag’ in (11) and (12), respectively.

(11) Labial Harmony

Ranking: *Dorsal, Agree >> Faith >> *Labial

‘bed’ /bɛd/		*Dorsal	Agree	Faith	*Labial
a. FFC	bɛd		*!		*
b. ☞	bɛb			*	**

(12) Velar Fronting and Labial Harmony (feeding interaction)

‘bag’ /bæg/		*Dorsal	Agree	Faith	*Labial
a. FFC	bæg	*!	*		*
b.	bæd		*!	*	*
c. ☞	bæb			*	**

The FFCs (11a and 12a) in the above tableaux violate Agree (with an additional violation being assessed by *Dorsal in the case of ‘bag’). This leaves the assimilated candidate (11b) as the winner for ‘bed’ words, even though it violates Faith.[1] In the case of ‘bag’ words, the unfaithful and unassimilated candidate (12b) violates Agree, leaving the assimilated candidate (12c) as the only viable option, even though it violates lower ranked Faith and *Labial.

To account for the observed counterfeeding interaction and the grandfather effect, we return to the issue of Agree’s encapsulated comparative markedness constraints, $_O$Agree and $_N$Agree, as defined in (7). Comparative markedness involves an enriched conception of conventional markedness constraints and was put forward as an amendment to classic Optimality Theory to resolve problems in accounting for counterfeeding interactions and grandfather effects (McCarthy, 2002). Earlier versions of Optimality Theory would have encountered a ranking paradox in the account of either of these two interactions for Velar Fronting and Labial Harmony. Under the conventional interpretation of markedness constraints, Agree would have needed to be ranked above Faith for some words and below Faith for other words in the same grammar. The innovation of comparative markedness is that it replaces conventional markedness constraints by splitting each into two separate, complementary constraints. One of these comparative markedness constraints assigns a violation to a marked element that is identical to the FFC (in some sense ‘old’ designated by the subscript$_O$ before the constraint name). The other complementary comparative markedness constraint assigns a violation to a marked element that is not identical to the FFC (in some sense ‘new’ designated by the subscript $_N$ before the constraint name). By splitting Agree into its two comparative

[1]It should be noted that Faith abbreviates a series of individual faithfulness constraints that are fixed universally in their ranking and that assign more serious violations to labial unfaithfulness than to coronal unfaithfulness (e.g. Prince & Smolensky, 1993/2004). Consequently, a candidate such as [dɛd] for input /bɛd/, which changes a labial to a coronal, would be eliminated in favour of the alternative unfaithful, but attested, winner [bɛb], which changes a coronal to a labial.

markedness constraints, $_O$Agree and $_N$Agree, we are free to rank each constraint independently of the other. This means, for example, that both constraints could be ranked above Faith in one grammar (equivalent to the conventional interpretation of Agree) to yield a feeding interaction, or that both could be ranked below Faith (again equivalent to ranking Agree below Faith) to prevent any instances of Labial Harmony.

One of the important differences between conventional markedness and comparative markedness is illustrated by the required ranking of these constraints in (13) and (14) to account for the observed counterfeeding interaction (e.g. Child 99). The main point to note in this case is that $_O$Agree must be ranked above Faith, and $_N$Agree must be ranked below Faith. In tableau (13) for 'bed', the FFC (13a) incurs a fatal violation of $_O$Agree because a labial and a coronal both occur in that word and are unchanged from the input. The assimilated candidate (13b) is thus selected as the winner. However, in tableau (14) for 'bag' words, note that the FFC (14a) is eliminated by its violation of either *Dorsal or $_O$Agree. Importantly, candidate (14b), which represents the unassimilated realization of Velar Fronting, does not incur a violation of $_O$Agree because the two different places of articulation in that word are not the same as in the FFC. Candidates (14b) and (14c) both violate Faith, passing the decision down to *Labial. The assimilated candidate (14c) incurs two violations of *Labial, whereas candidate (14b) incurs just one. This eliminates candidate (14c), favouring candidate (14b) as the winner. Although the winner does violate $_N$Agree because the labial and coronal in that candidate are not the same as in the FFC, that violation is rendered inconsequential because of the lower ranking of $_N$Agree.

(13) Labial Harmony

Ranking: *Dorsal, $_O$Agree >> Faith >> *Labial >> $_N$Agree

'bed'	/bɛd/	*Dorsal	$_O$Agree	Faith	*Labial	$_N$Agree
a. FFC	bɛd		*!		*	
b. ☞	bɛb			*	**	

(14) Velar Fronting counterfeeds Labial Harmony

'bag'	/bæg/	*Dorsal	$_O$Agree	Faith	*Labial	$_N$Agree
a. FFC	bæg	*!	*		*	
b. ☞	bæd			*	*	*
c.	bæb			*	**!	

The ranking of $_O$Agree and $_N$Agree must be just the reverse to account for the observed grandfather effect (e.g. Child 192), as shown in (15) and (16). In tableau (15) for 'bed' words, the FFC (15a) does not incur a violation of $_N$Agree because the labial and coronal consonants in that candidate are not new relative to the FFC. In fact, the FFC only violates lower ranked *Labial and $_O$Agree, but those violations are inconsequential because the assimilated candidate (15b) was eliminated by its violation of Faith.

(15) No Labial Harmony (grandfather effect)

Ranking: *Dorsal, $_N$Agree >> Faith >> *Labial, $_O$Agree

'bed' /bɛd/	*Dorsal	$_N$Agree	Faith	*Labial	$_O$Agree
a. FFC ☞ bɛd				*	*
b. bɛb			*!	**	

(16) Velar Fronting and Labial Harmony (grandfather effect)

'bag' /bæg/	*Dorsal	$_N$Agree	Faith	*Labial	$_O$Agree
a. FFC ☞ bæg	*!			*	*
b. bæd		*!	*	*	
c. bæb			*	**	

In tableau (16) for 'bag' words, the FFC (16a) incurs a fatal violation of *Dorsal, and the unassimilated candidate (16b), which reflects Velar Fronting, is also eliminated because of its violation of $_N$Agree. The only viable option remaining is the assimilated candidate (16c), which is chosen as the winner.

We have shown above that different permutations in the ranking of constraints (especially comparative markedness constraints) can account for the observed occurrence and nonoccurrence of Velar Fronting and Labial Harmony and for the full range of attested interactions between these processes. However, we have not yet accounted for the apparent implicational relationship between Labial Harmony and Velar Fronting. That is, we have not provided for the principled exclusion of one of the logically possible but unattested instances of the typology, namely the occurrence of Labial Harmony without Velar Fronting. As our account currently stands, it would be possible to generate Labial Harmony without Velar Fronting by simply ranking Agree (or any of its comparative markedness constraints) above Faith with *Dorsal ranked below Faith. The theory clearly needs to be constrained in some way to preclude this unattested ranking/grammar. Our proposal takes advantage of an architectural element of the theory that has been employed to account for other implicational relationships by installing certain constraints in a fixed universal ranking (e.g. Prince & Smolensky, 1993/2004). To capture the implicational relationship between Labial Harmony and Velar Fronting, we propose that *Dorsal be fixed in its ranking over Agree (or any of its comparative markedness constraints) as shown in (17).

(17) Fixed universal ranking

Ranking: *Dorsal >> Agree (or $_O$Agree/$_N$Agree)

Fixed constraint rankings of this sort tend to reflect harmonic scales that capture generalizations about the relative markedness of certain structures along some dimension such as place of articulation or sonority (e.g. Prince & Smolensky, 1993/2004; de Lacy, 2006). The particular fixed ranking in (17) is a partial elaboration of the scale for place of articulation and captures the generalization that dorsal place is more marked than any other combination of place features within a word, which is more marked than any other single place feature with in a word. The fixed ranking in (17) has all of the following desired typological consequences: If any of the Agree constraints were ranked above Faith, *Dorsal would also necessarily be ranked above Faith, providing for the feeding interaction. If *Dorsal were ranked below Faith, any and all versions of Agree would also necessarily be ranked below Faith, providing for the absence of both Velar Fronting and Labial Harmony. The permutability of the comparative markedness constraints also allows one of the comparative markedness constraints to be ranked above Faith, with the other comparative markedness constraint ranked below Faith. However, *Dorsal would necessarily also have to be ranked above Faith, thereby providing for the counterfeeding interaction or the grandfather effect, depending on which comparative markedness constraint is ranked above Faith. Finally, if Agree were ranked below Faith, *Dorsal could still be ranked above Faith. This is because the fixed ranking requires only that one dominate the other, not that they be immediately adjacent in the hierarchy. This provides for the occurrence of Velar Fronting without Labial Harmony.

The display in (18) revises the earlier constraint hierarchies by incorporating the fixed ranking of *Dorsal over the Agree constraints and summarizes the required constraint rankings for each of the attested typological possibilities.

(18) Summary constraint rankings for the typology

(a) Neither Velar Fronting nor Labial Harmony

Faith >> *Dorsal, *Labial >> ${}_{O}$Agree, ${}_{N}$Agree

(b) Velar Fronting without Labial Harmony

*Dorsal >> Faith >> *Labial >> ${}_{O}$Agree, ${}_{N}$Agree

(c) Labial Harmony without Velar Fronting (unattested and excluded in principle)

(d) Feeding interaction

*Dorsal >> ${}_{O}$Agree, ${}_{N}$Agree >> Faith >> *Labial

(e) Counterfeeding interaction

*Dorsal >> ${}_{O}$Agree >> Faith >> *Labial >> ${}_{N}$Agree

(f) Grandfather effect

*Dorsal >> ${}_{N}$Agree >> Faith >> *Labial, ${}_{O}$Agree

An important consequence of this account is that we now have an explanation for the different targets of Labial Harmony. That is, coronals alone will be targets of Labial Harmony when Velar Fronting counterfeeds Labial Harmony. In other instances, coronals and velars will both be targets of Labial Harmony when Velar Fronting feeds Labial Harmony. Finally, velars alone will be targets of Labial Harmony when Velar Fronting and Labial Harmony participate in a grandfather effect. These findings raise a number of theoretical and clinical issues relating to the behaviour and interaction of these and other error patterns and identify areas for future research, which we take up in the following discussion.

Discussion

Comparison of findings from other studies

The findings in this article differ in important respects from two recent studies that have investigated other error patterns that have the potential to interact in similar ways. The first of these examined the two presumably independent processes of Deaffrication (e.g. ‘chew’ realized as [tu]) and another version of Consonant Harmony, namely Velar Harmony (e.g. ‘duck’ realized as [ɡʌk]), in a cross-sectional and longitudinal study of the sound systems of young children with phonological delays (Dinnsen et al., 2010b). The general predictions about these two processes were the same as in this study, namely that, if the two processes were to co-occur, they would have the potential to interact in any one of three ways in words such as ‘cheek’ and ‘duck’. That is, one predicted option would be for Deaffrication to feed Velar Harmony (e.g. ‘cheek’ [kik], ‘duck’ [ɡʌk]). A second predicted option would be for Deaffrication to counterfeed Velar Harmony (e.g. ‘cheek’ [tik], ‘duck’ [ɡʌk]). The third option would be for these two processes to participate in a grandfather effect (e.g. ‘cheek’ [kik], ‘duck’ [dʌk]). Although Deaffrication and Velar Harmony were found to interact in all logically possible ways, as in this study, the most significant difference was that the two error patterns did not participate in an implicational relationship. That is, Deaffrication and Velar Harmony were found to be truly independent processes – with either process occurring without the other, with neither process occurring or with both co-occurring and interacting in one of the three predicted ways. Apparently all of the constraints responsible for this typology were freely permutable with no fixed rankings being necessary.

The longitudinal results further suggested that there was a characteristic developmental trajectory of change in these interactions. That is, feeding interactions changed into counterfeeding interactions or grandfather effects before arriving at the end-state grammar of English. The trajectory was unidirectional, meaning that counterfeeding interactions and grandfather effects never changed into a feeding interaction. It is not possible to ascertain a developmental trajectory of change for Velar Fronting and Labial Harmony in this study because it was based on cross-sectional evidence alone. It must remain for future research to establish the attested trajectory for Velar Fronting and Labial Harmony by tracking the longitudinal development of individual children who present with each of the attested instances of the typology. However, if we were to extrapolate from the earlier study, we might speculate that the developmental sequence would begin with the two processes co-occurring and interacting in a feeding relation. The next step would be to change to either a counterfeeding interaction or a grandfather effect, followed by the loss of Labial Harmony while retaining Velar Fronting. The final step would be to the end-state grammar in which both processes have been suppressed. Such a trajectory would, at least, correspond with widely held assumptions about the relative markedness of interactions and initial- and end-state grammars. Although an optimality theoretic account was not formulated for the findings in Dinnsen et al. (2010b), those facts are equally amenable to a comparative markedness account.

The other study (Dinnsen et al., in press) evaluated the same predictions about the occurrence and potential interactions of two other commonly occurring error patterns, namely Labialization (e.g. ‘thumb’ realized as [fʌm]) and Dentalization (e.g. ‘sun’ realized as [θʌn]). These two processes were found to be independent, at least in terms of their occurrence (i.e. one without the other), their non-occurrence and to some extent their co-occurrence – just as with Deaffrication and Velar Harmony, but unlike the typology for Velar Fronting and Labial Harmony in this study. The more surprising result was that, when these two processes co-occurred, they participated exclusively in a counterfeeding interaction (e.g. ‘sun’ [θʌn], ‘thumb’ [fʌm]). The predicted feeding interaction (e.g. ‘sun’ [fʌn], ‘thumb’ [fʌm]) and the predicted grandfather effect (e.g. ‘sun’ [fʌn], ‘thumb’ [θʌm]) failed to be attested. Assuming that the absence of a feeding interaction and a grandfather effect in this instance reflects a systematic and non-accidental gap, the theory must be constrained to provide for the principled exclusion of these interactions when certain markedness constraints are active. The theoretical restrictions proposed in that study forced the feeding interaction to be circumvented by an alternative process of Stopping (e.g. ‘sun’ [tʌn], ‘thumb’ [tʌm]). Additionally, the absence of a grandfather effect in this instance was explained by exempting the markedness constraint against interdentals from being split into corresponding comparative markedness constraints.

The results from these various studies clearly converge on some points, but they also crucially differ on certain others. At the very least, they indicate that the behaviour of error patterns cannot simply be assumed; the occurrence and interaction of error patterns must be established on empirical grounds on a case-by-case basis. As other cases involving these same error patterns come to light, it should be possible to determine whether the various observations continue to hold up. It will also be equally important to examine the occurrence and interaction of other error patterns to determine their typological characteristics, especially because there are other possible types of interactions for other processes beyond those discussed in this paper. For examples of other types of interactions, see Dinnsen (2008c).

Two other published studies are notable for the issues they raise relative to our current findings. Let us first consider the study by Pater and Werle (2003), which examined directional effects of Consonant Harmony (i.e. progressive Vs. regressive assimilation) in younger typically developing children. Although the primary focus was on Trevor, they identified cases of children who exhibited the more general form of Consonant Harmony, which included both Labial Harmony and Velar Harmony concurrently. Although the two subtypes of Harmony behaved differently on several counts, the point relating to our findings is that the occurrence of velars, which served as triggers for Velar Harmony, might seem to undermine our claim that Labial Harmony depends on an active Velar Fronting process. Stated differently, how could velars occur and be available to trigger Velar Harmony, in apparent contradiction to Velar Fronting, if Labial Harmony were active? There are three points that should be kept in mind here. First, whereas the body of that paper makes no mention of Velar Fronting, the appendix to the paper does include additional crucial data from Trevor showing that velars were produced as coronals when followed by front vowels, which in turn were followed by a coronal consonant. A similar type of vowel-conditioned Velar Fronting has been documented elsewhere for other children (e.g. Camarata & Gandour, 1984; Dinnsen, 2008a). Additionally, Trevor's Velar Fronting process was active at the point Labial Harmony became active (age 1;5) and continued until age 2;2, severalmonths after Labial Harmony was suppressed (age 1;8). These longitudinal facts are displayed most clearly in the Figures on p. 393 and p. 405 of their paper. The second point to keep in mind in such cases is that Velar Fronting might be active (according to a 25% occurrence criterion) in some words, whereas other words might have velars being produced target-appropriately. Consequently, velars could be available in some words to trigger Velar Harmony, whereas other words at the same time might undergo Velar Fronting. Finally, Velar Fronting is a process that is often restricted to word-initial position, meaning that velars can be produced correctly in other contexts (e.g. Inkelas & Rose, 2007). In such cases, those contexts not affected by Velar Fronting could make velars available to trigger Velar Harmony. In sum, the identification of an active Velar Harmony process alone cannot be taken as evidence that Velar Fronting is not active in some words or in some contexts. Ultimately, both the cross-sectional and longitudinal findings from Pater and Werle (2003) provide additional valuable support for our claim that Labial Harmony depends on the occurrence of Velar Fronting, even though that might not have been the intent of the paper.

The other published study of interest to us here, namely the one by Inkelas and Rose (2007), adopts a very different perspective on the process of Velar Fronting. They argue that word-initial Velar Fronting is attributable to very young children's presumed articulatory limitations (and not a phonological process). The reasoning behind their claim is two-fold: First, word-initial position is considered a perceptually salient, strong context that tends to preserve contrasts in fully developed languages (rather than neutralizing them). A phonological rule restricted to word-initial position would, thus, not be a natural process. Second, they argue that very young children have a small oral cavity relative to a disproportionately large tongue body. They contend that, in the child's effort to produce a velar in the strong context of word-initial position, hyperarticulation occurs and inadvertently brings the tongue body into contact with the alveolar ridge, resulting in something that sounds like a coronal. We find these arguments to be less than compelling on several counts. First, a variety of other error patterns neutralizing place and/or manner distinctions in word-initial position, including Deletion, have been documented in young children's developing phonologies (e.g. Dinnsen & Farris-Trimble, 2008b, 2009). It is difficult to see how a small oral cavity and large tongue body could be implicated in all of these other error patterns. Second, the children with phonological delays who exhibit Velar Fronting tend to be older than the children Inkelas and Rose had in mind and have an oral anatomy that more closely approximates an adult oral cavity. Third, some children with word-initial Velar Fronting have also been shown to systematically replace word-initial coronals with velars as a result of Velar Harmony (e.g. Dinnsen & Farris-Trimble, 2008a), and yet other children have been shown to produce all coronals as velars as a result of Coronal Backing (e.g. Morrisette, Dinnsen, & Gierut, 2003). Additionally, although some children with Velar Fronting have been shown to acoustically differentiate derived coronals from underlying coronals (e.g. Weismer, 1984), it would be difficult to attribute this to an articulatory limitation, especially given that adult speakers of fully developed languages have been shown to make similar subtle acoustic differentiations in accord with a variety of underlying distinctions that are presumably merged perceptually (e.g. Dinnsen, 1985). Such subtle acoustic distinctions (also known as covert contrasts) may not be perceptually salient, but they do, at least, reflect systematic language-specific rules or phonetic implementation processes that respect underlying distinctions. Also, from a cross-linguistic perspective, Velar Fronting in children's early speech appears to be motivated by the same highly ranked markedness constraint, *Dorsal, evident in many languages of the world (e.g. Maddieson, 1984; de Lacy, 2006). Even the presumed contextual anomaly associated with Velar Fronting does not seem all that unusual given the many cases of children's other error patterns that have been shown to be restricted to word-initial position; see Dinnsen and Farris-Trimble (2008b, 2009) for examples from typical and atypical development and for a unified optimality theoretic proposal for dealing with developmental shifts in contextual prominence. In sum, the general approach adopted by Inkelas and Rose suggests that phenomena in developing sound systems that do not accord with phenomena in fully developed languages are somehow outside the realm of theoretical claims about language. Removing children's seemingly problematic phenomena from the domain of linguistic theories does little more than insulate those theories from inconvenient facts. Our own view is that developing phonologies, whether typically developing or delayed, provide an essential, equally informative window into the principles that govern language and language learning.

The above notwithstanding, it is widely acknowledged that long-distance consonantal assimilation of primary place features (i.e. Consonant Harmony) is a phenomenon that occurs exclusively in young children's developing phonologies (and not in fully developed languages). String-adjacent assimilations are, however, common cross-linguistically. This disparity between developing and fully developed languages has received much attention in the literature (e.g. Goad, 1997; Bernhardt & Stemberger, 1998; Pater & Werle, 2003; Dinnsen & Farris-Trimble, 2008b) with no clear resolve. It, thus, may well be that some of the details of the implementation of Consonant Harmony follow from developmental factors, such as planar segregation, the size of the lexicon and so on. Under this interpretation, the markedness constraint Agree might reflect a developmental process, and its fixed ranking below *Dorsal would install it in a position in the hierarchy that is more vulnerable (than non-developmental processes) to early demotion and suppression. For now, this must remain an open question for linguistic and/or developmental theories.

Variation

Variation is obviously a hallmark of developing phonologies. It is, thus, not surprising that our findings would have identified several types of system-internal variation. One type of variation was evident in the application of a process to some words and the non-application of that same process to other words with the same phonological characteristics. Any process that applied to fewer than 100% of relevant words would have been an instance of this type of variation. Another type of variation involved different error patterns for the same target sound in the same phonological context. All of the children evidenced this type of variation to some extent for at least one of the target sounds of interest. For example, Child 99's replacement of target coronals intervocalically in non-harmonizing context with a glottal stop or a palatal glide was an instance of two different options for dealing with intervocalic coronals. A third type of variation, namely the concurrent occurrence of a feeding and a counterfeeding interaction, is less well documented in the literature, but some cases have nonetheless been reported (e.g. Dinnsen et al., 2010b). This type of variation was evidenced in this article by Child 18, who subjected at least 25% of his 'bag'-type words to both Velar Fronting and Labial Harmony and another 25% or more of those same words to Velar Fronting without Labial Harmony. Although these various types of variation are interesting on both theoretical and clinical grounds, the point of this article has not been on variation, nor could we hope to do justice to a proper account of this variation here given the current state of knowledge of the factors that influence variation. However, various alternative optimality theoretic proposals have been put forward as possible accounts of variation. For an overview of some of the more promising proposals, see Coetzee and Pater (in press). In general, the approaches that have been adopted allow some constraints to be partially ranked, resulting in different rankings for different words, and/or they define some constraints in terms of lexical factors such as lexical category (e.g. noun vs. verb), word frequency or age of word acquisition. The nature of the data available to us in this study makes it difficult to evaluate these alternative proposals.

Clinical implications

The results from this descriptive study have a number of clinical implications that warrant future experimental validation. For example, consider the case of a child who presents with Velar Fronting and Labial Harmony applying in a feeding relation. The clinician would be confronted with several different treatment options, including among others, the choice of which error pattern to target for treatment and which words or word shapes to use in treatment. For example, we hypothesize that, if treatment were aimed at the suppression of Labial Harmony by teaching the child 'bed'-type words either in isolation or in contrast with (near) minimal pairs (e.g. 'bed' Vs. 'Bob'), the expectation would be that AGREE would be demoted below FAITH, resulting in the correct realization of 'bed' words. However, Velar Fronting would likely persist, requiring additional treatment aimed at that process. The reason behind this is that we saw that Velar Fronting can occur without Labial Harmony. An alternative treatment option for a feeding interaction involving Velar Fronting and Labial Harmony would be to focus treatment on the suppression of Velar Fronting alone by teaching the child 'key'-type words in isolation or in contrast with (near) minimal pairs (e.g. 'key' Vs. 'tea'). Notice that these treatment words would not include any of the triggers or contexts for Labial Harmony. We hypothesize that, because of the implicational relationship between Velar Fronting and Labial Harmony (*vis-à-vis* the fixed ranking of *DORSAL over AGREE), the demotion of *DORSAL below FAITH would result necessarily in the demotion of AGREE below FAITH. If Velar Fronting were suppressed, Labial Harmony would also necessarily be suppressed without ever directly treating that error pattern. Also, from a diagnostic perspective, if a child were to present with any evidence of velars undergoing Labial Harmony (e.g. 'bag' realized as [bæb]), the observed implicational relationship between Labial Harmony and Velar Fronting should tell us that the child will also have an independent problem of Velar Fronting in non-assimilatory contexts. A prospective clinical treatment study evaluating these predictions would provide valuable experimental evidence as a complement to our post hoc descriptive findings.

Conclusion

This article has attempted to establish the facts regarding the occurrence and interaction of the two error patterns of Velar Fronting and Labial Harmony in the sound systems of young children with phonological delays. The results revealed that the two processes are not entirely independent of one another. That is, Velar Fronting can occur with or without Labial Harmony or not at all, but Labial Harmony can occur if and only if Velar Fronting also occurs. It was further found that when the two processes co-occurred they interacted in any one of three ways –in a feeding relation, in a counterfeeding interaction or in a grandfather effect. Each interaction had the effect of targeting a different class of sounds for Labial Harmony. These results differed from those of other interacting error patterns, suggesting the need for additional studies that attempt to establish the behaviour of different error patterns on a case-by-case basis. A version of Optimality Theory employing a fixed ranking among certain constraints and permutable rankings among other constraints (especially comparative markedness constraints) was shown to provide a principled explanation for the attested instances of the typology with novel clinical implications.

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