The Production of Consonant Harmony in Child Speech

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Abstract

Consonant harmony, an assimilatory process affecting non-adjacent consonants, is found in both child and adult speech. While adult consonant harmony appears to be a phonological process, child consonant harmony has distinct properties that make a purely phonological explanation difficult. Child consonant harmony is found in the speech of some learners acquiring a language that does not have consonant harmony. Data from child consonant harmony is also distinct. In adult systems, sibilant harmony dominates (Hansson 2001), while in child systems velar and labial harmonies are most common (Stoel-Gammon and Stemberger 1994).

Recent work on other systematic errors in child speech has arguably revealed a non-phonological source for neutralizations and substitutions (Gibbon 1990, Scobbie et al. 2000). These two cases were previously explained via the phonology, however, acoustic and articulatory analysis show that the expected contrast was being produced by the speaker but was too weak to be perceived.

These studies raise the question of other systematic errors in child speech, such as consonant harmony. Could consonant harmony in children be the result of a developing motor system and not the phonology?

Previous work on child consonant harmony credits this process solely to the phonology e.g. Stoel-Gammon and Stemberger, 1994; Goad, 1995; Pater & Werle, 2001. A recent treatment by Hansson (2001), however, notes the similarities between consonant harmony and slips of the tongue. He concludes that while adult consonant harmony may be fully synchronic, it may have its source in the domain of speech planning. These similarities also call into question whether child consonant harmony is the result of this domain.

Having identified three possible sources for child consonant harmony; the phonology, a developing motor system and the domain of speech planning, a study will be presented that tests the hypothesis that child consonant harmony is the result of a developing motor system.

The results of both the articulatory and acoustic study indicate that the motor system is faithfully executing the command to produce a harmonized form. This is evidence that consonant harmony is not the result of a developing motor system. While no evidence is produced that contradicts a phonological treatment, the facts of child consonant harmony may be better explained as having a source in the domain of speech planning.
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Chapter 1
Introduction

Consonant harmony is a process by which a consonant assimilates to another, non-local consonant. It is a relatively rare property of the languages of the world that is well documented in Shaw (1991) and Hansson (2001). Consonant harmony is also found in the speech of children who are acquiring a language without consonant harmony. In these cases, CH lasts for a few months before the harmonized forms give way to the target forms. Child CH typically targets coronals, labials and velars and is triggered by velars and labials (Vihman 1978, Stoel-Gammon and Stemberger 1994).

1) Child velar harmony, Amahl stage 1, age 2;60 (Smith 1973)
   a. ˚gak  ‘dark’
   b. ˚gik  ‘drink’

While consonant harmony is found in both adult and child speech systems, they arise in crucially distinct ways. In mature systems, consonant harmony is acquired via primary linguistic data. In this case, consonant harmony is a productive process in the target language and is learned just as any other phonological process is learned. On the other hand, consonant harmony is also found in the speech of learners who are acquiring a language without consonant harmony, e.g., English. This means that for these speakers, consonant harmony cannot be the result of harmony in primary linguistic data and its presence must be explained in another fashion. If consonant harmony is not the result of external input to the system, it must have a source internal to the system. There are three systems that must be entertained as possible sources for child consonant harmony: the perceptual system, the grammar and the production system.

1.1 The perceptual system
If child CH were the result of the perceptual system, the target form would be mis-perceived as the harmonized form. For example, ‘dog’ would be perceived as ‘gog’. Alternatively, the child may have an incomplete representation for the harmonized form. Vihman (1996) explains how persistent speech errors could arise from the perceptual system.

"When first attempting a word, the child may be operating with an internal representation which is only partially correct. In time, this representation becomes more accurate."

1 Smith (1973) argues that misperception may be responsible for a few harmonized forms that persist after CH is generally lost.
as the child profits from additional exposure to the adult form. But the child may fail to notice the discrepancy between his or her initial internal representation and the adult surface form and could then persist in the perception-based error for some time." (p 155)

This hypothesis must overcome the evidence that indicates that children with CH have constructed the unharmonized target as their underlying representation. Children with CH have no trouble comprehending unharmonized forms. While there is some evidence that the perceptual system may play a role in some systematic errors in children\(^2\), no evidence has been presented that would support the perceptual system as a source for CH. Maintaining a perceptually-motivated hypothesis for CH, one must explain why the misperceived segments are among the first segments to be acquired. Stops can be produced (and therefore accurately perceived) in non harmony triggering environments. The segments targeted by harmony are also found in the most perceptually salient environment, word-initially.

1.2 The grammar
The second possible system-internal source for child CH is the grammar itself. This hypothesis claims that CH is the result of interference from adjustments to the grammar from other input. This is best understood in terms of an Optimality Theory grammar. Acquisition in OT is achieved via the re-ranking of constraints. The interference would come from the ranking of constraints to reflect other processes, which, as a consequence, create surface patterns not found in the target language.

1.3 The production system
The third system that could yield CH is the production system. This system can be broken down into two closely related sub-systems; motor-control and speech planning.

1.3.1 Motor Control
The motor system is responsible for executing a cognitive command, here from the language faculty, in terms of articulatory gestures. A child must develop these connections in order to produce speech. CH could result from this system’s inability to coordinate multiple articulatory gestures within a short sequence, yielding a more articulatorily consistent form\(^3\).

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\(^2\) Eilers and Oller 1976
\(^3\) See Plaut and Kello (1998)
1.3.2 Speech Planning

The domain of speech planning is responsible for speech errors in both children and adults. There is a strong argument to be made that errors in speech planning may yield consonant harmony. Hansson (2001) compares slips of the tongue with adult consonant harmony systems and, based on shared properties, concludes that while CH may be fully synchronic in adult speech, it has a source in the domain of speech planning.

Of these three systems, this work investigates the production system and specifically, motor control as a possible source for child CH. This choice was made for two reasons. First, articulatory data can be collected using ultrasound imaging. Second, results from Gibbon (1990) and Scobbie et al. (2000), which look at systematic errors in child speech, have yielded interesting results pointing to a source in motor control.

1.4

Previous studies on systematic errors in child speech

Gibbon (1990) and Scobbie et al. (2000) look at the phonetics of a case of substitution and neutralization, respectively, in child speech. The results show that the target segments were being produced, although the contrasts were either too weak to be perceived or were masked by the production of the substituted segment. The production of some aspect of the intended segment calls into question the traditional phonological analysis of these systematic errors as a categorical replacement of the target. If the expected contrast is being produced, however weak, it cannot have a phonological source as this would yield a categorical presence or absence of the target.5

These results point to the motor system as cause of systematic errors in child speech.

Here, developing motor control refers to the child’s ability to activate the appropriate articulators to produce the phonological target. This includes the relative timing of the articulators as well as any fine-tuning that is required to generate adult-like productions. During acquisition, we can assume that since motor control is still developing this will have an effect on data from child speech. This effect will be different from the data produced by a stable, already developed motor system. Following Gibbon (1990) and Scobbie et al. (2000), properties of child speech can be studied to determine a potential source resulting from the developing motor system by determining if the target sound

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4 This discussion will be limited to articulatory studies of child speech as these are more relevant to this study. See Macken and Barton (1980) and Weismer, Dinsen and Elbert (1981) for acoustic analyses of covert contrast.

5 But see Zsiga (1998) for a case of apparent gradient phenomenon in adult speech.
is being attempted by the learner. Since these cues are difficult to perceive, their detection must be aided by acoustic and articulatory analysis.

Having identified three potential sources for consonant harmony in child speech as a) the perceptual system, b) the grammar and c) the production system, which was further divided into the motor system and speech planning, a study will be presented that tests the hypothesis that consonant harmony arises from a developing motor system. This hypothesis is testable using ultrasound to monitor the movements of the tongue during productions of harmonized forms as well as with acoustic analysis. Tongue shapes of harmonized forms are compared to control forms in order to detect if the target segment is attempted alongside the harmonized segment. If the target segment is attempted by the speaker, we will have evidence pointing to a motor source for consonant harmony. This result would be in line with the results from Gibbon (1990) and Scobbie et al. (2000). If, on the other hand, there is no evidence that the target segment is being attempted by the speaker, we must look to a higher-level cognitive system in the production of consonant harmony in children. The results of this study show that there is, in fact, no attempt made by the speaker to produce the target segment during harmonized segments. Research presented in Hansson (2001) lends support to the hypothesis that consonant harmony is a phonological process that is motivated in the domain of speech planning.

This work is organized as follows. Chapter two presents the relevant literature on consonant harmony, representing the phonological and speech planning hypotheses. Chapter three focuses on the studies on covert contrasts in child speech presented in Gibbon (1990) and Scobbie et al. (2000) in terms of child consonant harmony. Chapter four presents an articulatory and acoustic study of consonant harmony and chapter five concludes.

**Chapter 2**

**Literature Review**

Child consonant harmony systems are analyzed as processes that are completely contained by the phonology in Stoel-Gammon and Stemberger (1994), Goad (1996) and Pater & Werle (2001).

The analysis in Stoel-Gammon and Stemberger (1994) argues for underspecification as one motivation for consonant harmony. Goad argues against this type of underspecification and assumes an OT analysis that uses ranked parse constraints for place of articulation as well as alignment
While these analyses vary in detail they all pinpoint the source of consonant harmony as phonological. A phonological analysis of child consonant harmony is typical but not necessarily a full account of this property.

This chapter presents three previous analyses of consonant harmony. The first analysis is from Smith (1973). This is a phonological view of child consonant harmony that is framed within the rule-based theory of SPE. The second approach, presented in Gafos (1999), focuses mainly on adult consonant harmony but does discuss child systems. OT motivates CH although the features are defined in terms of articulatory phonology as it is developed in Browman and Goldstein (1986, 1992). The last analysis, Hansson (2001), takes CH to have its roots in the psycholinguistic domain of speech planning.

2.1 Smith (1973)

Smith's analysis of Amahl's speech follows the theoretical framework laid out in SPE. He discusses A's phonology in terms of two systems; the first is that A's phonology is a mapping from adult English Standard Pronunciation i.e. that the underlying forms are assumed to be the adult surface form, and the second treats his developing phonology as an independent system.

A discussion presented on pp 178-181 concludes that a child's phonology is, in fact, a mapping from adult speech rather than an independent system unto itself.

In sum I conclude that a good case has been made for the claim that the child's lexical representations are in terms of the adult system, that the realisation rules also have some psychological validity, and that conversely there is little evidence—if any—to support the alternative hypotheses either that the child has his own system or anything more abstract than the adult system. p181

The following discussion of Smith's analysis includes only the most prolific rule for consonant harmony. The others have been left out, as their inclusion requires a detailed understanding of the data that is not relevant to this discussion.

A's speech shows assimilation of coronals to a following labial or velar.

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1 See Smith (1973) pp 55-75 for the details of the other rules.
2) Amahl stage 1, age 2;60

a. ɗɔ: ‘door’

b. ɗʌm ‘drum’

c. ɡʌk ‘dark’

d. ɡik ‘drink’

The rule that is responsible for harmony of coronals to following velars and labials was termed ‘optional’ at Stage 1 (age 2;60), as it operated only part of the time when preceding labials. Two rules are needed by Stage 3 (age 2;130) as coronal assimilation to labials occurs only with coronal nasals and continuants. These rules are:

i) \([+\text{coronal}] \rightarrow [-\text{coronal} -\text{anterior}] / \, [+\text{syllabic}] \, [-\text{coronal}, - \text{anterior}]\) 

and,

ii) \([+\text{coronal}] \rightarrow [-\text{coronal}, +\text{anterior}] / \, [+\text{syllabic}[-\text{coronal}, +\text{anterior}]\) 

\{[-\text{nasal}], [+\text{cont}]\}

Rule i) applies unrestricted to coronals before velars, while rule ii) applies only to coronal nasals and continuants before labials.

For example, rule i) yields;

[gigu] ‘tickle’

[ŋek] ‘neck’

While rule ii) yields;

[mibu] ‘nipple’

[maip] ‘knife’

but does not apply to;

[de:bu] ‘table’

[dep] ‘stamp’

CH is easily captured using the above rules. Now we must turn to the question of why a child learning English would have CH in the first place.

Unfortunately, Smith simply states that CH is universal in child speech⁴. This claimed universality is one of the properties that Smith argues makes child speech simplified in production. Smith also argues that cluster reduction is universal and that like most of the realization rules, this serves to make child productions simpler⁵.

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² Smith (1973) p.162
³ Smith (1973) p.162-176
If CH is a universal property of child speech, why doesn't it occur in the speech of all children? Vihman (1978) found CH in 7 out of 13 children acquiring various languages and Stemberger and Stoel-Gammon (1991) estimate that it is found in 50-70% of children acquiring English. Unless some children lose CH before it can show up in their first productions, a proposition that would be difficult to test, the evidence indicates that CH does not occur in 100% of children.

Smith (1973) provides us with a rule-based phonological analysis of child CH. Given that not all children have this property; it remains unclear as to what motivates CH.

2.2 Gafos (1999)

Gafos (1999) argues that consonant harmony is a local assimilatory process and is therefore mediated by the intervening vowel. Articulatory phonology is assumed as is put forth in Browman and Goldstein (1986). Articulatory phonology formalizes articulatory cues into the features over which the phonology operates. The model organizes gestures and their timing on a gestural score. This theory is able to capture some phonological processes such as allophonic variation and phonetic phenomena such as the differences seen between slow and fast speech.

Evidence to support this view comes from the nature of segments involved in consonant harmony in adult systems. The majority of adult consonant harmony systems involve coronals. Gafos discusses this bias in terms of the articulators used in the production of coronals and vowels. The major articulator of coronals is the cross-section of the tongue-tip blade. This articulator can be active independent of the tongue dorsum, which is the major articulator for vowels. He concludes that a vowel can therefore be produced with no significant acoustic consequences arising from flanking coronals in a CVC sequence.

This description does not explain the absence of velar or labial harmony in adult systems only that if the spreading feature is coronal, it is predicted not to be perceived on the intervening vowel.

Gafos discusses child CH systems as distinct from adult systems. He concludes that this property of child speech is not consonant harmony based on an analysis of this process in Stemberger and Stoel-Gammon (1991), which uses tier segregation. Gafos rejects tier-segregation as a viable theory for CH data replacing it with segmental copying. Note that ruling out the mechanism does not allow one to conclude that the process in question is not CH. A second reason is based on a description of child CH given by Goldstein (no reference
This account describes child consonant harmony as a property of a developing motor system.

While no actual evidence is given that child consonant harmony is distinct from that found in adult systems, we should note that Gafos's theory that consonant harmony is a local assimilatory process hinges on the coronal bias in adult systems. It is the set of features involved in adult harmony systems that allow for no acoustic consequence on an intervening vowel. This bias is not, however, a property of child consonant harmony systems where velar and labial harmony is more common than coronal harmony (Stoel-Gammon and Stemberger 1994). Gafos's theory therefore must not include child systems in order to maintain the premise that consonant harmony is a local assimilatory process that is mediated by an intervening vowel. If child consonant harmony were a local assimilatory process, the spreading labial or velar feature would be perceived on an intervening vowel.

Gafos presents a phonetically elegant description of spreading. A spreading feature from C\, to C\, in a C\,C\,C\, configuration is not rendered inactive during the production of the intervening vowel. Instead it falls out from the nature of the articulations involved that the spreading feature is not heard on the vowel. No attempt is made, however, to account for what motivates consonant harmony and the facts used to formulate this theory are not applicable to cases of child harmony.

This analysis was presented as it provides a non-standard account of CH as a phonetic phenomenon. We saw that this account does not capture the facts associated with child CH. If this account of adult CH is correct we must then view adult and child CH as distinct processes. We must also conclude, given the facts of child CH, that it cannot have the phonetic analysis discussed above.

The next section presents an argument that, while adult CH systems are fully synchronic, they have a source in the psycholinguistic domain of speech planning.

2.3 Hansson (2001)

Hansson compares consonant harmony systems with speech errors. According to Hansson, both processes are characterized by the following properties;

i) relative similarity of the segments involved
ii) directionality (left-to-right vs. right-to-left assimilations)
iii) transparency of intervening segments
iv) the palatal bias effect
In both consonant harmony systems and slips of the tongue, the relative similarity of a potential target and trigger add to the likelihood that these two segments will undergo the process. These two segments must agree in terms of certain features in order to be considered for either process.

Another similarity between slips of the tongue and consonant harmony lies in the directionality of the processes. Right-to-left, or anticipatory assimilations may be the default direction for consonant harmony as well as slips. Hansson explains this directionality effect for slips in terms of speech planning. As one element is being produced an upcoming element is being planned. This planning stage interferes with the production stage resulting in harmony.

The third parallel between slips of the tongue and consonant harmony is the transparency of intervening segments to the assimilatory process. While the argument presented in Gafos (1999) claims that the intervening segments are, in fact, affected by the assimilating feature, Hansson points out that this has not yet been tested instrumentally and therefore maintains the claim that intervening segments are not affected. This claim is also maintained in the case of slips. Articulatory data collected during slips of the tongue show that the assimilating feature is not maintained through the intervening segments.

The final shared property of slips and consonant harmony systems is termed the palatal bias. The palatal bias is a generalization over both processes where alveolars are replaced by palatals but not vice versa. Hansson cites many empirical studies including Stemberger (1991) that show that this bias holds true of speech errors involving alveolars. This same bias is found to hold in a cross-linguistic survey of CH systems. While the palatal bias holds true of adult CH systems, it is missing from child CH possibly because CH occurs predominantly before children have acquired palatoalveolar fricatives and affricates. As was noted in the discussion of Gafos (1999) above, velar and labial harmonies outnumber coronal harmony in child CH data.

The parallels drawn between CH and slips of the tongue motivate the conclusion that CH systems have their roots in the same domain as slips of the tongue, i.e. in the domain of speech planning. Generalizing this conclusion to child systems, we hypothesize that while child CH may be a fully synchronic phonological process, it may have a source in the domain of speech planning. This hypothesis is able to motivate CH in child systems, avoiding the problem encountered in a traditional phonological account, which provides no explanation of a source for CH as it is not present in the target language.

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4 Hansson (2001) p450 claims that left-to-right assimilations may be restricted to stem-affix environments cf. Stemberger (1989).

5 Hansson p457 citing Pouslier et al. (1999).
2.4 Summary

This chapter presented three distinct views on consonant harmony. Smith (1973) claims that CH in child speech is universal and therefore provided by universal grammar. The approach taken in Gafos (1999) uses OT and grounds his constraints in an articulatory phonological theory of features. This view saw child CH systems as necessarily distinct from adult CH systems. The approach taken in Hansson (2001) drew parallels between CH and slips of the tongue, motivating a source for CH in the domain of speech planning.

While the phonological approaches presented above are all able to model CH, they differ in explaining why CH occurs in the first place. Smith (1973) claims that CH is universal and therefore innate; an OT model can claim it arises from the interaction of constraints; Gafos (1999) argues that CH in adults is a local spreading and is therefore another case of local assimilation. Finally, Hansson (2001) draws parallels between slips of the tongue and adult CH implicating a source in the domain of speech planning.

Another approach appeals to the developing motor system. This approach has proven fruitful in two previous studies of systematic errors in child speech, neutralization and substitution. The next chapter presents two studies that motivate a motor development analysis of processes previously credited to a child's phonology.

Chapter 3
Motor Explanations for 'Systematic Errors' in Child Speech

The studies presented in Gibbon (1990) and in Scobbie et al. (2000) provide strong support for an explanation of perceived 'systematic errors' in child speech based in a developing motor system. This approach takes the source of these perceived errors out of the phonology and into a performance subsystem. This chapter will first discuss what is meant by a developing motor system. Section 3.2 will present the studies in Gibbon (1990) and Scobbie et al. (2000), and then ask if the facts of child CH lend themselves to a motor analysis.

3.1
What is meant by a 'Developing Motor System'?

It is not always clear what is meant by the term 'developing motor system'. The motor system is a part of the performance system and therefore outside of the
grammar. Other aspects of the performance system include memory, time and organization of perceptual strategies (Chomsky 1968). Although it is not the goal of this section to provide a theory of performance, distinctions within this system are crucial to this discussion.

During speech production, the output of the grammar provides the input to other systems before the final physical output yielding a speech signal. Two of these systems are speech planning and the motor system. We know that the grammar's output goes through these two systems because of the distinct errors that they incur on the final output. Speech planning errors include substitutions and segment exchanges.

3) Stemberger (1989,1991)

a. Substitution

That would be one RAY to raise me. “way”

b. Reversal

Why was SHE surprised? “she surprised”

A developing motor system is required to form associations between the commands it receives and the instantiation of these commands in the physical domain (see Kent 1992 for a more in-depth treatment). This raises the question as to the source of certain errors. The co-ordination of gestures in time is one aspect of acquiring speech. It is safe to say that certain errors in temporal co-ordination are due to speech planning, but could some errors be attributed to the developing motor system?

Work on interlimb co-ordination (Kelso et al. 1979) has shown that the motor system groups actions into one event. Using two hands to point to the same object is not the result of many commands but rather is the result of one command to point. The acquisition of co-ordination in the speech motor system is assumed to be the same process. The child acquiring motor skills for speech must learn to co-ordinate his/her articulators into events. At this level we expect errors that stem from the development of the motor system’s formation of articulatory events. Errors produced during this stage of processing would include the mis-timing of individual gestures. Note that all the necessary gestures may be executed but their incorrect relative timing may yield an utterance that is perceived as lacking some gestures due to potential masking by other gestures.

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1 While the question of which unit of speech is considered an event, gesture, segment, syllable or word is interesting, it is beyond the scope of this paper.
Having considered what is meant by a developing motor system and its potential effect on a learner's speech, we will now turn to two studies presenting errors that may be considered of this type.

3.2 Gibbon (1990) and Scobbie et al. (2000)

This section reports on the findings of two studies on perceived 'systematic errors' in child speech. The term 'systematic error' is maintained here in keeping with the literature despite its problematic use of the term 'error'\textsuperscript{2}.

3.2.1 Gibbon (1990)

Gibbon (1990) looks at the movement of the articulators during a surface neutralization of the alveolar-velar distinction. Using electropalatography, Gibbon tested two sisters one of whom failed to produce the alveolar-velar contrast. VB, the older sister at 6:2 years, produces a perceptible contrast while MB, aged 4:10 years, produces alveolars that are perceived as velars in words as well as in isolation. The EPG results show that MB's tongue placements is, in fact, different for velars and alveolars. That the alveolars are perceived as velars is due to the tongue tip being released before the tongue body. VB, on the other hand, has mastered the timing of the release sequence for alveolars and they are therefore perceived as such. This may reflect MB's developing motor system with respect to temporal co-ordination.

3.2.2 Scobbie et al. (2000)

Scobbie et al. present the results of a study of the speech of a phonologically disordered child.

This study compared the initial [t], [d], and [st] segments of the child at age 4:1, all of which seemed to be neutralized to [t] in onsets. For example, forms such as 'tie', 'dye' and 'sty' were produced as apparent homophones. After an instrumental analysis of his speech, it was found that contrasts were being made to distinguish the three sounds. The breathy phonation made after English aspirated stops is reflected in a steeper measure for spectral tilt. A difference in spectral tilt marks a distinction between aspirated and non-aspirated stops. By the next stage in his development the contrast was perceivable to listeners.

We can conclude that either a) the articulators were given a command from the phonology to produce a weak contrast, or that b) the phonology gave the categorical command to distinguish these sounds but another system interfered with their realization. Either way, this is not a case of phonological neutralization, as a complete neutralization does not occur.

\textsuperscript{2} It is not clear that the output is erroneous given that it may not be divergent from the system that produced it.
Scobbie et al. conclude that the covert contrast may have its source in an immature system of mapping between the phonetics and the phonology. The exact source for the contrast problem is outside of the child’s phonology proper.

3.3 Is CH comparable to other ‘systematic errors’?

There is a crucial distinction to be made between the phenomena studied in Scobbie et al. (2000), Gibbon (1990) and child consonant harmony. Scobbie et al. discovered a covert contrast in an apparent phonological neutralization of three sounds: /st/, /t-/ and /d-/ All three were perceived as /t-/ in all instances where it was found in the onset.

Likewise, the subject of Gibbon’s study produced alveolars that were consistently perceived as velars every time it was attempted. The neutralization is sensitive only to its position and the replacement of alveolars with velars is context-independent. CH is distinct from these two cases as it is featurally conditioned. Consider the conditions under which harmonized forms are produced. The following forms show regressive velar harmony that targets coronals. By comparing the first two forms with the last two it is clear that not all coronals are replaced by velars. In fact, only coronals that occur before a velar will undergo harmony.

4) Velar harmony (Amahl stage I, Smith 1973)
   a. do: ‘door’
   b. dam ‘drum’
   c. ga:k ‘dark’
   d. gi:k ‘drink’

This conditioning feature is not a property of the phenomena studied in Gibbon and Scobbie et al. This difference may be crucial to the explanation of these phenomena. Speakers with CH are capable of producing the replaced segment in contexts where the conditioning environment is not met. Amahl’s stage 1 data clearly shows his ability to produce a coronal when there is no velar that follows.

This chapter introduced two important studies on child speech. Focusing on what appeared to be a phonological process of alveolar replacement and neutralization, it was found that the intended contrast was being made. These results indicate that what was once thought to be a phonological process might
have a source in the developing motor system of the child. These two across-the-board replacements were compared to CH. CH is feature-dependent. Both conditioned and across-the-board replacements are properties that set child speech apart from adult speech and they are therefore considered together under the name 'systematic error'. It is unclear at this point if the distinction between CH and across-the-board replacements will be reflected in terms of the source of the replacements. The next chapter presents a study, which directly addresses this question.

Chapter 4
Articulatory & Acoustic Study of Child Consonant Harmony

This chapter will present both an articulatory and acoustic study of child consonant harmony where the initial glide in 'yellow' is harmonized with the following lateral. This example of harmony differs from the most commonly discussed harmony in children in the following ways. First, the more commonly documented cases of child consonant harmony involve the assimilation of coronals to upcoming labials and velars. Second, children showing this labial and velar harmony are typically younger than 24 months while our subject is 39 months. These two distinctions could be attributed to order of acquisition of certain sounds since laterals are acquired late while labials and velars are acquired relatively early (Templin 1957). The third difference lies in the degree of productivity of harmony. In most reports, harmony involves more than one form. Our subject shows harmony only in the form for 'yellow'. When we consider the properties of 'yellow' in English we see that it is unique as the only form that is mono-morphemic with a strong-weak stress pattern having a /j/.../l/ onset sequence (Stemberger, p.c.). We could therefore argue that our subject has consonant harmony in all forms with these characteristics.

The articulatory data gathered for this study allows us to test the hypothesis presented in Gafos (1999). Gafos argues that CH is a case of local spreading and is therefore mediated by the intervening vowel. Using ultrasound images, we will be able to see if the spreading features are, in fact, present on the intervening vowel.

The articulatory study is presented first in section 4.1, the acoustic analysis is presented in section 4.2 and the results are discussed in 4.3.
4.1 Articulatory study

This study compares the movement of the articulators during the production of regular forms with the form containing a harmonized [l]. The current study looked for a source in motor development for CH as was done in Gibbon (1990) and Scobbie et al. (2000) for across-the-board replacements of alveolars and neutralization, respectively.

KW, the subject of this study has lateral harmony in the form for 'yellow'. This harmony is regressive (right to left), and targets the initial glide.

5) KW’s harmonized form, age 3:3
   'yellow' \([lelo]\)
   KW is capable of producing the target sound [j] in initial position as the following forms show.

6) [j] produced word-initially
   'yoyo' \([jojo]\)
   'yogurt' \([jogrt]\)
   KW is also capable of producing a [j] V [l] sequence.

7) 'yelling' \([jelin]\)
   If consonant harmony is caused by the phonology or by inaccurate speech planning, we expect the harmonized sound to be made in the same way as a non-harmonized version of the same sound in the same environment. For example, we expect the initial [l] in the harmonized form [lelo] ‘yellow’ to be made the same way as the non-harmonized [l] in ‘lemon’. On the other hand, if harmony is the product of a developing motor system then this difference may be reflected in productions. In this case, the level of development of the articulators may be insufficient to hit the proper targets in the allotted time. Given this hypothesis, we can look for an attempt made by the speaker to hit the ‘lost’ target, e.g. the [j] in ‘yellow’.

Looking specifically at /l/, a study by Sproat and Fujimura (1993) reveals which gestures we expect for adult English speakers. Sproat and Fujimura looked at the differences, both acoustic and articulatory, between English dark and light /l/. X-ray microbeam data were gathered for /l/ in various prosodic positions. The articulatory correlates of /l/ were assessed by tracking pellets placed on the tongue tip, on the middle of the tongue blade and on the tongue dorsum.

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1 According to Nittrouer (1993), we expect a difference between adult and child productions in terms of the duration of segments; a child’s segment being longer. We expect that the gestures involved, however, will be adult-like.
/l/ was found to be comprised of two gestures. There is both a fronting of the tongue tip as well as a raising and retraction of the tongue body. Based on this study we expect initial [I] to be produced by fronting the tongue tip and backing the tongue dorsum.

If, however, the initial segment in harmonized 'yellow' is being produced with imperceptible cues for [j], we expect to find an advancement of the tongue root as well as a raising of the tongue mid, the gestures associated with [j] (Gick 1998). Because [j] and [I] are so different articulatorily, we should be able to differentiate the predictions of the different approaches. In this study, I collect ultrasound data to determine whether the initial [I] of [lelo] is a true [I] or that it shows some of the characteristics of a [j].

8. Schematic images depicting the expected tongue shape for [I] and [j].

Two questions will be addressed. First, are the gestures for harmonized [I] the same as the gestures for its unharmonized counterpart? Second, if they are different, does this difference reflect an attempt to hit the 'lost' target, [j]?

The rest of this chapter is organized as follows. Section one discusses the methods of this study including a description of the subject, the apparatus used, the procedure and analysis. Section two presents the results of the study and section three is a discussion of these results.

4.1.1 Methods

a. Subject

The subject, KW, is a bilingual learner of English and German, age 3;3. His exposure to English is estimated by his mother to be 70%. No hearing problems were found when tested by his family physician. Based on informal testing, he is normally developing phonologically.

b. Apparatus

Ultrasound imaging allows for a non-invasive view of the movement of soft tissue. A dynamic two-dimensional image of the tongue can be seen when the
probe is placed under the chin. See Gick (in press) for a complete description of ultrasound use for linguistic data collection. The placement of the tongue during speech was assessed using a SonoSite 180 Plus portable ultrasound machine with a SonoSite C15/4 2MHz MCX transducer. The images are recorded by a digital video camera with a frame rate of 30 frames/sec and are then transferred to a computer for analysis within Adobe Premiere and LIHmage.

c. Procedure

The following are the tokens gathered from the speaker, including the harmonized form and the control forms. The control forms are required to compare the gestures made in a on-target form to the harmonized form. These forms have varied places of articulation for the second consonant in order to control for possible regressive assimilation effects on the initial segment. Initial [l] was used for the control forms as syllable-initial [l] is articulatorily distinct from coda [l] (Gick 1998).

Control forms were selected to match syllable number and stress pattern (strong-weak) of the harmonized form 'yellow'. [l]-initial words with the vowel [e] were used, to control for the effects of coarticulation; they provide details of what is expected for [l] before the vowel in question. [j]-initial words were placed before [o], because these words were more easily elicited with pictures. If there are coarticulatory effects, these [j] tokens should be slightly less high and front than before [e], but this is unlikely to matter.

9) Harmonized and control forms

i) harmonized form

yellow [lelo]

ii) control forms

lemon
lego
lettuce
yoyo
yogurt

The subject was seated on his mother's lap during collection. The transducer was held against the subject's jaw by an assistant who monitored the image on a screen for optimal placement to produce a midsagittal image of the tongue. Data was gathered with the aid of pictures and objects presented to the speaker. The speaker was shown a picture and asked 'What's this?' For the form 'yellow' the question was asked of the lemon, 'What colour is this?' Given the age of the
subject, the session was limited to less than fifteen minutes and as a result only two to three tokens of each form were collected.

While head-correction can be used for consistent ultrasound images, the subject was too young to accommodate this added procedure.

d. Analysis
The movement of the articulators during the production of harmonized forms was compared to the on-target gestures made in the control forms. Measurements were made of cursor placement via visual inspection of the relative position of the tongue tip, the tongue mid, the tongue dorsum and the tongue root. While this approach does not yield results as accurate as with head correction, the relative values for each measurement are consistent.

4.1.2 Results
This section presents the results of the articulatory analysis using ultrasound images. Part one will show that KW’s production of harmonized [I] is similar to his production of a ‘true’ [I]. Part two will present an analysis of the intervening vowel in the harmonized form in terms of Gafos’ theory presented in section 2.2 of the literature review.

4.1.2.1 Comparing harmonized [I] to ‘true’ [I].
Ultrasound images showing KW’s production of initial [j], [I] and harmonized [I] are presented below. Images were chosen based on their representation of the most full realization of the gestures for the segment in question. The tongue tip is on the left of the image, the tongue root on the right. Some images show more of the tongue root than others due to the angle at which the transducer was held during data collection. In these cases, a white line has been added, reflecting the point between the tongue dorsum and the tongue root, where the other images end. This will aid in comparing images.
Image 10.a shows that the production [i] involves the raising of the tongue mid as well as the advancement of the tongue root.

During production of initial underlying /l/ the tongue tip (TT) raises to the alveolar ridge (not visible here), while the tongue dorsum (TD) retracts. Below are images showing the shape of the tongue for the initial [i] of the control forms.

b. lemon - Frame shown is 100ms from start of token and 167ms before vowel.
c. lettuce - Frame shown is 200ms from start of token and 133ms before vowel.

10.c Ultrasound image of KW's production of initial [ɪ] in 'lettuce'.

d. lego - Frame shown is 133ms from start of token and 200ms before vowel

10.d Ultrasound image of KW's production of initial [ɪ] in 'lego'.
Below is an ultrasound image for comparison of the initial [l] in 'yellow' to underlying initial [l] of the control forms given in 10) b-d.

11) [lelo] - Frame shown is 167ms from start of token and 167ms before vowel.

The movement of the articulators during the production of the initial segment in 'yellow' [lelo] was qualitatively similar to the production of initial 'real' [l]. There was no raising of the tongue mid and no advancement of the tongue root, the gestures we expect if there was an influence on production from [j].

4.1.2.1.1 Tongue root retraction

Tongue root retraction in the harmonized [l], reproduced in 12a. below, can be demonstrated by comparing it to the retracted tongue root during the production of [e] in 'lemon'. The distance from the transducer to the outer edge of the tongue root is 28mm in [lelo] and 27mm for the [e] in lemon. Compare this to a distance of 19mm for the advanced [j] of 'yoyo'.
12)

a. Tongue Root of [l] in ['le'] measuring 28mm.

b. Tongue Root of [e] in 'Lemon' measuring 27mm.
c. Tongue Root of [j] in 'yoyo' measuring 19mm.

The measurements taken of the various parts of the tongue for all tokens are given in the table below. These figures illustrate variability within each form, which is typical of child speech (e.g. Ferguson and Farewell 1975).

<table>
<thead>
<tr>
<th>TOKEN</th>
<th>TONGUE TIP</th>
<th>TONGUE MID</th>
<th>TONGUE DORSUM</th>
<th>TONGUE ROOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 'Lellow'</td>
<td>153</td>
<td>139</td>
<td>141</td>
<td>98</td>
</tr>
<tr>
<td>2</td>
<td>116</td>
<td>114</td>
<td>147</td>
<td>113</td>
</tr>
<tr>
<td>3</td>
<td>127</td>
<td>124</td>
<td>131</td>
<td>99</td>
</tr>
<tr>
<td>4</td>
<td>130</td>
<td>129</td>
<td>138</td>
<td>109</td>
</tr>
<tr>
<td>5</td>
<td>118</td>
<td>118</td>
<td>136</td>
<td>N/A</td>
</tr>
<tr>
<td>1 'Lemon'</td>
<td>115</td>
<td>114</td>
<td>150</td>
<td>114</td>
</tr>
<tr>
<td>2</td>
<td>140</td>
<td>132</td>
<td>132</td>
<td>111</td>
</tr>
<tr>
<td>3</td>
<td>123</td>
<td>120</td>
<td>131</td>
<td>98</td>
</tr>
<tr>
<td>1 'Lego'</td>
<td>135</td>
<td>126</td>
<td>160</td>
<td>113</td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>114</td>
<td>138</td>
<td>104</td>
</tr>
<tr>
<td>3</td>
<td>114</td>
<td>112</td>
<td>154</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>128</td>
<td>128</td>
<td>168</td>
<td>151</td>
</tr>
<tr>
<td>1 'Lettuce'</td>
<td>135</td>
<td>133</td>
<td>153</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>133</td>
<td>131</td>
<td>145</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>146</td>
<td>141</td>
<td>145</td>
<td>100</td>
</tr>
<tr>
<td>1 'yoyo'</td>
<td>N/A</td>
<td>156</td>
<td>154</td>
<td>110</td>
</tr>
<tr>
<td>2</td>
<td>N/A</td>
<td>176</td>
<td>132</td>
<td>66</td>
</tr>
<tr>
<td>1 'yogurt'</td>
<td>94</td>
<td>161</td>
<td>133</td>
<td>107</td>
</tr>
</tbody>
</table>

Table 13. Measurements of the relative position of the TT, TM, TD and TR of all tokens. N/A indicates that measurement was not possible due to image quality.
The mean values for the measurements in table 13) are presented in table 14) below.

<table>
<thead>
<tr>
<th></th>
<th>TONGUE TIP</th>
<th>TONGUE MID</th>
<th>TONGUE DORSUM</th>
<th>TONGUE ROOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Lellow'</td>
<td>128.8</td>
<td>124.8</td>
<td>138.6</td>
<td>104.75</td>
</tr>
<tr>
<td>'Lemon'</td>
<td>126</td>
<td>122</td>
<td>137.67</td>
<td>107.67</td>
</tr>
<tr>
<td>'Lego'</td>
<td>124.25</td>
<td>120</td>
<td>155</td>
<td>122.67</td>
</tr>
<tr>
<td>'Lettuce'</td>
<td>138</td>
<td>135</td>
<td>147.67</td>
<td>99.5</td>
</tr>
<tr>
<td>'Yoyo'</td>
<td>166</td>
<td>143</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>'Yogurt'</td>
<td>94</td>
<td>161</td>
<td>133</td>
<td>107</td>
</tr>
</tbody>
</table>

Table 14. Mean values for tongue measurements.

In order to show that no individual token of [lelo] shows an influence from [j], the following table provides the range for each [l]-initial token.

<table>
<thead>
<tr>
<th></th>
<th>TONGUE TIP</th>
<th>TONGUE MID</th>
<th>TONGUE DORSUM</th>
<th>TONGUE ROOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Lellow'</td>
<td>116-153</td>
<td>114-139</td>
<td>131-147</td>
<td>98-113</td>
</tr>
<tr>
<td>'Lemon'</td>
<td>115-140</td>
<td>114-132</td>
<td>131-150</td>
<td>98-114</td>
</tr>
<tr>
<td>'Lego'</td>
<td>114-135</td>
<td>112-128</td>
<td>138-160</td>
<td>104-151</td>
</tr>
<tr>
<td>'Lettuce'</td>
<td>133-146</td>
<td>133-141</td>
<td>145-153</td>
<td>99-100</td>
</tr>
</tbody>
</table>

Table 15. Range values for tongue measurements of [l]-initial forms.

It can be seen from the table above that no token of [l] in [lelo] is outside of the range of variability seen in the target [l] forms with the possible exception of the tongue tip in the first token of 'yellow'; note that the tongue tip in [j] is so low that it could not be measured, so this extreme high value for [l] is not [j]-like.

It should be noted the statistical power of this study is low due to the small number of tokens. It is possible that additional repetitions would uncover a difference. However, as there was no indication of any qualitative presence of an influence from /j/, this seems unlikely.

4.1.2.2 Analysis of the intervening vowel

Gafos (1999) argues that CH is a case of local spreading mediated by the intervening vowel. The articulatory data collected for this study allows us to test this hypothesis. Vowel tokens in [lelo] can be analyzed to see if [e] is affected by consonant harmony.
The following images show the tongue shape for the vowel in a harmonized form as well as images for the non-harmonized vowel in 'lemon'.

a. Tongue shape of [e] in [lelo]

b. Tongue shape of [e] in 'lemon'.

These images show that the tongue shape during the production of the intervening vowels for the harmonized and non-harmonized forms are essentially the same. This is evidence against the theory presented in Gafos (1998, 1999), which states that in consonant harmony, the intervening vowel
will be affected by the spreading feature. It is this hypothesis that allowed him to propose that consonant harmony is a local assimilation process. The images above, and the measurements below, show that the spreading feature does not affect the intervening vowel.

17) Table 17. Measurements of the relative position of the TT, TM, TD and TR for [e] in tokens of [lelo] and ‘lemon’. N/A indicates that measurement was not possible due to image quality.

The mean value for each position shows the equivalence of both cases of [e].

18) Mean values

Note the values for the tongue root. This slight difference in tongue root means for ‘yellow’ and ‘lemon’ is well below the tongue root value for [I] in table (21), so it is unlikely to derive from coarticulation with [I].

4.2 Acoustic analysis

Formant values for the initial segments of all tokens were identified automatically and confirmed visually within Praat. Tokens were digitized at 44100 Hz. The expected values for the first and second formants in [I] and [J] in adult speech are given for comparison in table 19. Note that the expected values are higher for children due to their smaller vocal tracts.  

2 Acoustic analysis of child speech is less accurate than adult speech due to the loss of frequency information resulting from larger gaps in harmonics.
19) Formants values for [i] and [j] in adult speech (Ladefoged 1993)

<table>
<thead>
<tr>
<th></th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>[i]</td>
<td>250</td>
<td>1200</td>
</tr>
<tr>
<td>[j]</td>
<td>280</td>
<td>2250</td>
</tr>
</tbody>
</table>

Formant values for initial [i] (harmonized and underlying) and initial [j] are presented in the table below.  

20) Formant values for initial segments, [i] and [j].

<table>
<thead>
<tr>
<th>TOKEN</th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. lego 1</td>
<td>499</td>
<td>1682</td>
</tr>
<tr>
<td>2. lego 2</td>
<td>566</td>
<td>1631</td>
</tr>
<tr>
<td>3. lego 3</td>
<td>634</td>
<td>1952</td>
</tr>
<tr>
<td>4. lego 4</td>
<td>482</td>
<td>1530</td>
</tr>
<tr>
<td>5. lemon 1</td>
<td>527</td>
<td>1586</td>
</tr>
<tr>
<td>6. lemon 2</td>
<td>520</td>
<td>1716</td>
</tr>
<tr>
<td>7. lemon 3</td>
<td>527</td>
<td>1611</td>
</tr>
<tr>
<td>8. lettuce 1</td>
<td>582</td>
<td>1620</td>
</tr>
<tr>
<td>9. lettuce 2</td>
<td>463</td>
<td>1695</td>
</tr>
<tr>
<td>10. lettuce 3</td>
<td>521</td>
<td>1516</td>
</tr>
<tr>
<td>11. yellow 1</td>
<td>500</td>
<td>1669</td>
</tr>
<tr>
<td>12. yellow 2</td>
<td>685</td>
<td>1128</td>
</tr>
<tr>
<td>13. yellow 3</td>
<td>491</td>
<td>1664</td>
</tr>
<tr>
<td>14. yogurt 1</td>
<td>547</td>
<td>N/A</td>
</tr>
<tr>
<td>15. yogurt 2</td>
<td>431</td>
<td>3304</td>
</tr>
<tr>
<td>16. yoyo 1</td>
<td>545</td>
<td>2820</td>
</tr>
<tr>
<td>17. yoyo 2</td>
<td>486</td>
<td>3921</td>
</tr>
</tbody>
</table>

The formant values of the harmonized [i] in ‘yellow’ are equivalent to the values for the target initial [i] in ‘lego’, ‘lemon’ and ‘lettuce’. The average values are as follows.  

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The number of tokens used differs in the articulatory and acoustic analysis due to the quality of ultrasound images or acoustic signal.  

Note that the mean F2 value for harmonized [i] is less [j]-like than target [i], due to one token.
21) Average formant values for each segment

<table>
<thead>
<tr>
<th></th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>target</td>
<td>532</td>
<td>1654</td>
</tr>
<tr>
<td>harmonized</td>
<td>559</td>
<td>1487</td>
</tr>
<tr>
<td>[j]</td>
<td>502</td>
<td>3348</td>
</tr>
</tbody>
</table>

These results confirm what was found with the articulatory study. The formant values for harmonized and target [i] are equivalent.

4.3 Discussion

The goal of this study was to compare the production of harmonized [i] to a target [i]. The articulatory study looked at the movement of the articulators during the production of consonant harmony using ultrasound imaging. Ultrasound images of harmonized [i] were compared to target initial [i] in order to see if they were different gesturally. The acoustic study compared formant values for all three segment types. The results of both studies suggest no difference between these two cases of surface [i]. Harmonized [i] is not being affected by an attempt to produce [j]. This is consistent with the idea that the motor system is being given the same command in the production of these two segments.

Two predictions were provided at the beginning of this study. These predictions were as follows. If CH is the result of a command from the phonology, we expect there to be no influence from the intended segment, /j/, on the harmonized form. On the other hand, if harmony is the result of a developing motor system which is unable to fully realize a command for the target segment /j/ in 'yellow', we expect the initial [i] to reflect an attempt to produce the intended [j]. The results of both the articulatory and acoustic study indicate that a true [i] and the harmonized [i] are not distinct.

At its most basic level, we know that the subject’s motor system is capable of producing the target segment as is evidenced by [jojo] 'yoyo'. Arguments have been made that a child’s first productions are undifferentiated gestural patterns and are therefore larger than a segment (Menn, 1983; Studdert-Kenedy 1990). In this case we could hypothesize that there is a problem instantiating a glide-vowel-liquid pattern. Evidence against this comes from KW’s ability to produce the form ‘yelling’.

The results of this study satisfy the first prediction; the motor system is being given the same command in both cases, to produce [i]. CH is therefore not the result of a developing motor system.
We are left with a systematic property of child speech for which there is no evidence of a motor-based problem. Maintaining the traditional position that a categorical property is phonological, we may conclude that CH is a phonological process for children. The problem remains as to the motivation for this process as it does not have its source in the target language.

Recall the arguments made in Hansson (2001) that draw striking parallels between adult consonant harmony and speech errors.5 Both were found to share the following properties:

i) relative similarity of the segments involved

ii) directionality (left-to-right vs. right-to left assimilations)

iii) transparency of intervening segments

iv) the palatal bias effect

Based on these shared properties, Hansson (2001) concludes that while adult consonant harmony is a phonological process, it has a source, as do slips, in the domain of speech planning. These properties, in terms of child consonant harmony are addressed below.

a) relative similarity of the segments involved

Articulatorily, [j] and [l] are similar in terms of airflow and timing patterns. They are different, however, in terms of place of articulation, as can be seen from the schematic image of the tongue shapes for both segments reproduced below.

22)

While both segments involve vocalic movements of the tongue body, the production of [j] involves an advancement of the tongue root as well as the raising of the tongue mid. [l], on the other hand, has a retracted tongue root and a backing of the tongue dorsum as well as a tongue tip gesture. In the more common types of child CH, however, the segments involved are most often stops and therefore identical in terms of manner of articulation.
b) directionality
In Vihman’s (1978) study of child consonant harmony, 67% of the harmonized forms were found to be regressive, while 33% were progressive. This is consistent with slips, where right to left assimilations predominate.

c) transparency of intervening segments
The transparency of intervening vowels was observed in this study via ultrasound imaging. No effect from the harmonized [i] was maintained during the production of the intervening vowel.

d) the palatal bias effect
The palatal bias effect is not widely observed in child consonant harmony. Vihman (1978) reports only 5% of harmony involving fricatives as opposed to 66% involving stops. Our ability to observe the palatal bias in children may be impeded by the relatively late acquisition of fricatives as compared to stops. More relevant to child CH are the velar and labial biases for stops reported in Stemberger (1991) and Stemberger and Stoel-Gammon (1991). These biases apply to both child CH as well as to adult slips.

Because of the parallels between slips of the tongue and child CH, we must entertain the hypothesis that they are both the product of the same system, that of speech planning.

If child CH, like adult CH has its source in the domain of speech planning, it must then become phonologized since it is consistent and persists for several months. This process is maintained until the speaker receives enough data to revise the grammar and CH is lost.

Chapter 5 Conclusion
Due to the lack of work on the influence of extra-phonological domains in child speech, systematic errors in child productions, such as consonant harmony, are attributed solely to the phonology, a relatively well-researched domain. The purpose of this study was to address the question of the source of consonant harmony in child speech. Including the phonology, three sources were identified that inform the output of child speech. These are a) the phonology proper b) speech planning and c) the motor system. Given functional concerns of testability, as well as the success of the Scobbie et al. and Gibbon studies, the motor system was chosen for a study into the source of consonant harmony.

Three different treatments of consonant harmony were presented in chapter 2. These included Smith’s rule-based analysis within an SPE framework, the treatment of harmony as a case of local feature spreading in Gafos (1999), and
Hansson’s phonological account of consonant harmony that has a source in the domain of speech planning.

Chapter 3 presented a discussion of CH in relation to the replacement and neutralization processes studied in Gibbon (1990) and Scobbie et al (2000). Here we saw how CH differs from the other studies in that it is dependent on a feature to trigger the change. For example, a child with CH is capable of producing the target segment when it is not followed by a harmony-triggering consonant. This was contrasted with the across-the-board replacement and neutralization cases presented in Gibbon (1990) and Scobbie et al. (2000). It may be the case that the featurally conditioned environment for CH is an indication that the motor system cannot be implicated in this systematic error. More studies of the type presented here will need to be conducted on cases of systematic errors in child speech in order to draw such conclusions.

An articulatory and acoustic study was presented in chapter 4 in order to determine if the intended target of consonant harmony could be detected in the output. Ultrasound imaging was used to track the gestures of harmonized forms. These images were compared to the control images gathered from an on-target production of the same segment.

Comparing harmonized gestures to un-harmonized gestures for initial [l], it was found that there was no difference in their production. Acoustic analysis comparing the formants of harmonized [l] with a target [l] likewise revealed no difference in their acoustic properties. Unlike the Gibbon (1990) and Scobbie et al. (2000), results that showed the presence of the ‘replaced’ gesture, we were unable to find any indication that the ‘lost’ target was being attempted.

The results presented here suggest that child CH is not a product of a developing motor system. Given its persistence and systematicity, child consonant harmony appears to be a phonological property. Its presence in the speech of children who are not exposed to consonant harmony via the target language points us to a system-internal source. As was done by Hansson (2001) for adult consonant harmony, parallels were drawn between child consonant harmony and slips of the tongue. These similarities suggest that both properties arise from the same system, that of speech planning.
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