THE ROLE OF CONSONANT HARMONY IN CHILD LANGUAGE[1]

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1 Introduction

Consonant Harmony (hereinafter, CH) is defined as assimilation between non-adjacent consonants (e.g. Cruttenden 1978). It is attested both in adult and child language but with some apparent differences between the two types of grammar. CH is relatively rare in adult languages (Hansson 2001)[2] and in addition, there are no known languages with primary place of articulation harmonies (Pater and Werle 2003, among others). An example for adult CH is shown in (1).

(1) Sibilant Harmony in Adult Language: Navajo (Athapaskan; USA)

a.	/ʃi-taːʔ/	'my father'	→ [ʃi-taːʔ]
b.	/ʃi-zid/	'my scar'	→ [si-zid]

(Hansson 2001)

This is a case of minor place of articulation harmony that affects sibilants: all coronal fricatives and affricates assimilate in the minor place feature [anterior] to the rightmost sibilant in the word.

[1] This is a part of an ongoing study; see Gafni (to appear). I would like to thank Outi Bat-El for her guidance through this study, and Evan-Gary Cohen for his helpful comments and suggestions along the way. I would also like to thank the audiences of IATL 27 and the TAU interdisciplinary colloquium for their insightful questions and comments on my presentation.

[2] Hansson (2001) provides a list of about 100 languages and dialects (including some extinct ones) that have some form of CH (some have more than one type of CH). He does not specify the number of languages examined in total but claims that the survey was extensive. If this datum represents all existing cases of CH then only about 2% of the world's languages (6909 according to Lewis 2009) have CH.

CH in child language differs from the adult type both in abundance and typology. First, it has been widely reported in the acquisition process of many languages, even those that have no CH in the adult form; examples include, English (Smith 1973), Dutch (Fikkert, Levelt and van de Weijer 2002), Greek (Tzakosta 2007), Estonian (Vihman 1978) and Hebrew (Ben-David 2001), to name a few. Second, not only does primary place of articulation harmony exist in child language, but it is also the most common type of child CH (Goad 1997).[3] Examples for primary place of articulation harmony in child language are shown in (2).

(2) Primary Place Harmony in Child Language

a.	Full harmony (English):	/dɔg/	‘dog’	→ [gɔg]
b.	Partial harmony (Hebrew):	/ˈkelev/	‘dog’	→ [ˈkelez]

(2a) is a case of *full harmony*, where the *target* of assimilation (i.e. /d/) is produced identically to the *trigger* (/g/). (2b) demonstrates *partial harmony*, where the result of the assimilation ([z]) differs from the trigger ([l]) in manner of articulation.

One of the main research aspects of child CH is its function. CH is commonly considered as a simplification mechanism which helps the child taking over the task of language acquisition. It may replace consonants the child has not yet mastered or reduce word complexity to help the child focus on new prosodic structure (Vihman 1978, Waterson 1978, Donahue 1986, Ben-David 2001, among others).

Another important, but often neglected issue is the relation of CH to other child language phenomena. CH is only one of many phonological processes attested in child's speech while being rare or completely absent from the ambient language. These processes (see Grunwell 1982/1984), all presumably serve the same purpose (i.e. speech facilitation), include *consonant deletion* (e.g. English /dʒuːs/ ‘juice’ → [du]), *stopping* of fricatives (English /feɪs/ ‘face’ → [peɪt]), *velar fronting* (English /bæk/ ‘back’ → [bæt]) and *reduplication* (English /pʊdiŋ/ ‘pudding’ → [pʊpʊ]) among others. Most studied treated CH in isolation; however, as is often the case, a certain consonant substitution resulting in a harmonic form can also be described as a non-assimilatory substitution. Stoel-Gammon & Stemberger (1994) and Tzakosta (2007) explicitly address this problem and separate the clear cases of CH from the ambiguous ones. Fikkert & Levelt (2008) take this issue further and claim that CH in child's Dutch is not a true assimilatory process but rather an “epiphenomenon”, i.e. an incidental surface realization of other phenomena (such as lexical overgeneralizations made by the child).

This paper presents a developmental study on two children acquiring Hebrew. The findings indicate that CH is driven mainly by prosodic rather than segmental factors. However, it seems that CH has a marginal role (at least for the participants of this study) compared to other strategies such as deletion and non-assimilatory substitutions. Crucially, I argue that the study of CH is severely limited by the fact that the motivation behind a given phonological process is hidden. This opacity prevents a certain identification of the status of many harmonized utterances, as they can be attributed to common non-assimilatory substitutions.

[3] The claim that child CH involves mostly changes in primary place features is also reflected from the relative significance that place harmony receives in the literature compared to manner harmony.

2 Research Method

The database for this study comprises of transcribed speech samples from two typically-developing Hebrew-acquiring children. The participants were a boy (SR) between ages 1;02.00 and 2;03:24 years (Lustigman 2007) and a girl (RM) between ages 1;03.13-2;11.28 years (Levinger-Gottlieb 2007). They have been audio-recorded in weekly sessions for a period of several years while interacting with the investigators and occasionally additional participants (mostly family members). The data, mainly in the form of spontaneous speech samples and some elicitation tasks (picture naming and telling stories from picture-books) have been collected and transcribed in the frame of the Tel Aviv University *Child Language Project*.[4]

To evaluate the status of CH in the phonology of a given child, I examined a large portion of the child's productions. This includes most of the target words attempted by the child which are potential candidates for CH, namely, words with at least two non-adjacent consonants.[5] I considered only token words for which a clear relation between input and output consonants could be established (at least under reasonable assumptions).[6]

For all the examined token words, the relations between input and output consonants were coded according to different phonological processes. In addition, every consonant substitution occurred in a harmonic environment was marked as possible CH (e.g. for /ken/ 'yes' → [ten] the relation between /k/ and [t] was coded as velar fronting + possible CH and the relation between target and output *n* was coded as faithful).[7] The purpose of this coding system is to help assessing the abundance of CH compared to other phonological processes. After identifying cases of CH, I turn to investigate the characteristics of the process. This includes general properties such as directionality and type of assimilation, and also the properties of the consonants involved in the process (i.e. triggers and targets).

3 General Corpora Analysis

The following table indicates the sizes of the examined corpora in terms of token and type words. The table includes also the number of words undergoing segmental substitutions in harmonic environments for each child (the entire period of study is covered).

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[4] The project was supported by ISF grant #554/04 (2004-2008) with Outi Bat-El and Galit Adam as principal investigators.

[5] Words that do not qualify as candidates to undergo CH are words with one consonant (e.g. /po/ 'here') and words in which all consonants are clustered (e.g. /dli/ 'bucket'). For simplicity sake, I also did not analyze productions which have a prefixed particle (e.g. /ve+gam/ 'and also') and productions resulting from word blending (e.g. /aʁ'gaz χol/ 'sandbox' → [gað'χol]). In any case, these utterances showed little evidence for harmonic substitutions, with perhaps only one notable exception - SR's productions for /bob ha+banaj/ 'Bob the builder (animated character)' which was often pronounced as [bona'naj]. In addition there was little if not any evidence for CH across word boundaries in both children.

[6] Examples for excluded words due to non-clarity: /jal'da/ 'girl' → [taχ] (RM 1;07.10), /ka'duʁ/ 'ball' → ['buma] (SR 1;03.14)

[7] Assimilation to a string adjacent consonant is not considered as case of CH. This is true even for target words that contain a consonant with the relevant harmonic feature, which is not string adjacent to the changed consonant (e.g. /li**f**'toaχ/ → /[liʃ'toaχ] is not CH even though the change /f/ → [ʃ] could theoretically be triggered by *l*).

(3) Corpora Sizes and Harmonic Segmental Substitutions

	SR		RM	
Total Corpus				
Tokens	11388		16746	
Types	1336		1705	
Harmonized tokens (% of corpus tokens)	301	(2.6%)	615	(3.7%)

It is important to note that at this point I do not address the question of whether the harmonic substitutions result from assimilation (see §4). I use the term *harmonic* in reference to the environment of the utterance, and reserve the term *assimilation* when referring specifically to the process known as CH.

As this is study is concerned with the relation between CH and other phonological processes, it is worth examining the general behavior of the consonant systems of the children. Table (4) summarizes three major behavior types of consonants: faithful production, deletion, and feature change. In this context, harmonic substitution is considered to be a case of feature change, and thus the class of feature changes is divided into substitutions in harmonic and non-harmonic environments.

(4) Consonants

	SR		RM	
Total	31485		44912	
Faithful (% of total)	26965	(85.6%)	35107	(78.2%)
Deletion (% of total)	3574	(11.4%)	5715	(12.7%)
Feature changes	946		4090	
Non-harmonic (% of total)	638	(2%)	3417	(7.6%)
Harmonic (% of total)	308	(1%)	673	(1.5%)

Notes:

a. All cases of feature changes are treated as one kind of phonological behavior. I separate them according to the nature of change in the next section when trying to differentiate between assimilatory and non-assimilatory substitutions.
b. Cases of metathesis (rare) are registered as faithful productions of the consonants involved, provided that no additional feature changes have occurred.

c. Substitutions of a coronal fricative by another coronal or dental fricative (e.g. /siʁ/ 'pot' → [θiʁ]) are considered as faithful productions. The reason for this is that both children use these substitutions very frequently. SR in particular seems to lack good control of stridents while being rather faithful in general, and classifying the stridents alternations as faithful prevents the masking of his good phonological skills.
d. Vowel changes of any kind are not considered in this paper, as well as differences in prosodic structure between the target and the output, which may result from deletion or insertion.

Examining the details in (4), it can be seen that the children have somewhat different developmental tracks, even though they are both considered as typical developers. RM is quite an average developer showing a significant amount of substitutions. SR, on the other hand, is a fast learner exhibiting a high rate of faithful productions and a marginal use of substitutions (with the exception of strident alternations). This difference between the children regarding the use of substitutions has a major influence on the analysis of CH as will be discussed in the next section.

4 Substitutions Classification

In this section I examine the set of consonant substitutions in order to identify cases of CH. Some cases are most likely assimilatory as they involve a substitution that is unattested or very rare in non-harmonic environments (e.g. the /v/-[n] substitution in /ʔaviˈron/ 'airplane' → [ʔaniˈon]). On the other hand, many substitution types are common enough in both harmonic and non-harmonic environments (e.g. the fronting of /k/ in /ken/ 'yes' → [ten] vs. /ˈkova/ 'hat' → [ˈtova]). In such cases it is difficult determining whether substitution in a harmonic environment is the result of CH or of a non-assimilatory process. This section attempts to resolve this ambiguity.

The following tables compare different types of substitution in harmonic and non-harmonic environments. The counts refer to the entire examined corpora. The results are categorized into groups according to the affected feature. Tables (5)-(7) summarize simple feature changes in voice, Place of Articulation (PoA) and Manner of Articulation (MoA), respectively. Appendix A provides examples for the different processes. The tables in (8) present cases of combined changes in place and manner, in terms of specific segments or feature classes. Since there are many types of combined changes these tables provide only the most notable cases. The full lists appear in Appendix B.

(5) Voice

Type	SR		RM	
	Harmonic	**Non-Harmonic**	**Harmonic**	**Non-Harmonic**
Voicing	30	54	17	121
Devoicing	2	31	51	540

The results in (5) strongly suggest that voice changes occur regardless of environment, as there are much more non-harmonic cases of (de)voicing than harmonic cases. This implies that assimilation of voicing alone does not exist as an independent process (cf. Vihman 1978). Taking this into consideration, I ignore voice changes when dealing with place and manner changes, that is, I treat substitutions like /k/ → [t] and /k/ → [d] as identical.

(6) Place

Type		SR		RM	
		Harmonic	**Non-Harmonic**	**Harmonic**	**Non-Harmonic**
Labial	→ Coronal	40	17	31	18
	→ Dorsal	6	2	3	1
Coronal	→ Dorsal	30	2	15	9
	→ Labial	28	4	16	17
Dorsal	→ Coronal	13	8	121	200
	→ Labial	5	10	5	14

(7) Manner

Type		SR		RM	
		Harmonic	**Non-Harmonic**	**Harmonic**	**Non-Harmonic**
Plosive	→ Nasal	7	5	3	15
	→ Fricative	1	0	25	34
	→ Affricate	0	7	3	37
Coronal Plosive	→ [l]	—	—	4	6
Fricative	→ Nasal	3	1	—	7
	→ Plosive	36	53	55	267
Coronal Fricative	→ [l]	3	0	—	—
Nasal	→ Plosive	6	3	62	70
	→ Fricative	2	0	5	13
/n/	→ [l]	—	—	1	15
/l/	→ [n]	0	1	4	23
Approximant	→ Plosive	21	3	9	45
/l/	→ Fricative	—	—	5	4
/ʁ/	→ [χ]	1	4	21	78
/χ/	→ [ʁ]	0	3	2	22

(8) Combined PoA and MoA

Type		SR		RM	
		Harmonic	**Non-Harmonic**	**Harmonic**	**Non-Harmonic**
Sonorant	→ [j]/[w]	1	31	8	327
Approximant	→ [l]	4	3	2	20
/j/, /ʁ/	→ [d]/[t]	2	0	20	7
/h/	→ [j]	—	—	1	6
/l/	→ [ʁ]	4	0	0	3
	→ [m]	0	3	2	7
/n/	→ [ʁ]	1	0	—	—
/ʃ/	→ [m]	10	0	—	—
/v/	→ [n]	11	0	—	—
	→ [d]/[t]	—	—	6	0

The tables above suggest that some of the harmonic substitutions observed are likely to result from CH, and some are probably not. Still, there are some processes whose status cannot be determined with certainty, either because the numbers are rather small (e.g. labial → dorsal) or due to notable differences between the children (e.g. approximant → plosive). The second point is especially important - many of RM's harmonic productions can be attributed to phonological processes other than assimilation. In contrast, most of SR's harmonic productions involve substitutions that are rare in non-harmonic environments. Such differences are problematic since they suggest that phonological processes might have arbitrary motivations. Arbitrariness of this type is implausible in general and especially when it concerns well attested phonological processes (see Grunwell 1982/1984 and Ben-David 2001 among others).

This last difficulty can be at least partially resolved by considering the data in (4) - SR has a low tendency to substitute consonants, so even if he uses a phonological process that is common among children (such as nasal stopping), it is harder to dismiss it as non-assimilatory due to lack of counter evidence. On the other hand, RM has a rich enough "repertoire" so it is easier to distinct her use of assimilation from other common phonological processes. In light of the discussion above I adopt the following semi-quantitative criterion for identifying non-assimilatory substitutions:

(9) **Non-assimilatory substitutions:** A certain type of substitution is non-assimilatory if it occurs significantly enough in non-harmonic environments for at least one child, and there is no strong counter evidence from other children.

In setting this criterion I put stress on linguistic as well as on statistical factors, since statistical tests alone may not always suffice to tease apart the assimilatory from the non-assimilatory substitutions. In some cases a statistical test may be inapplicable if there are not enough tokens containing the substitution in question. In addition, the results of a test may be misleading due to biased token frequencies. For example, 14 out of the 21 cases of harmonic approximant stopping for S are productions of /ˈkanguru/ ‘kangaroo’ as [guˈgum] and other similar variants. These productions are suspicious for two reasons: first, they are used persistently for 3 months, which is quite unusual, at least for SR. Second, they contain an epenthesized consonant of an unclear source. Altogether, it seems like that these productions result from bad lexical coding rather than from an active consonant harmony rule, and therefore I exclude them. To summarize, the non-assimilatory substitutions obtained using (9) appear in (10).

(10) Non-assimilatory substitutions

(De-)voicing	Nasal → Plosive
Dorsal → Coronal	ʁ ↔ χ
Dorsal → Labial	Sonorant → Glide
Fricative → Plosive	Sonorant → [l]
Plosive → Affricate	/l/ → Nasal
Plosive → Fricative	/h/ → [j]

For the rest of the analysis, I exclude the types of substitution specified in (10), although it is important to stress that it is possible that some of these harmonic substitutions do result from CH.

In addition to the substitution types presented above, there are also many harmonic productions whose nature remains unclear for different reasons. Especially notable are instances in which both the consonants involved acquire a feature that is not present in the target word, and thus there is no clear identification of the trigger and target (e.g. /liχˈluχ/ ‘dirt’ → [niχˈtut]). In total, SR has 24 such problematic productions and RM has 145. I do not deal with these cases in this paper (See more in Gafni to appear).

To conclude this section, I have shown that many productions with harmonic forms are likely to result from non-assimilatory substitutions. In many of these cases the result is a less marked segment than the target or there is a great similarity between the target and the result. (cf. Stoel-Gammon & Stemberger 1994, Ben-David 2001, Tzakosta 2007). After excluding the non-assimilatory and unclear substitutions I am left with 145 assimilatory tokens for SR and 141 tokens for RM. These are rather small numbers, which indicates that CH has a minor role for both children as they prefer to use deletion and non-assimilatory substitutions.

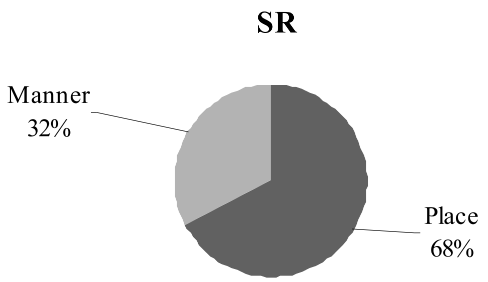
5 Properties of Consonant Harmony

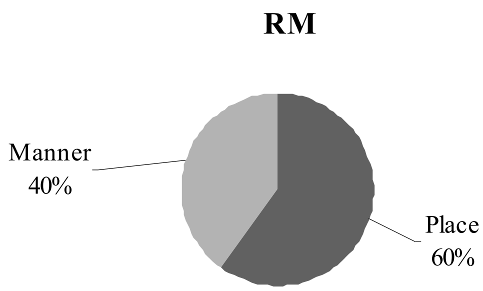
In this section, I analyze the properties of the productions suspected to result from CH, starting with the general properties of the process.

5.1 Type

CH can involve a change in *Place of Articulation* (e.g. /meno'ʁot/ 'lamps'→ [neno'ʁot]), *Manner of Articulation* (e.g. /laʔa'sot/ 'to do' → [se'ʃot]), or both (e.g. /ʔaga'la/ 'cart' → [ga'ga]).[8] Chart (11) demonstrates the distribution between place and manner changes. Cases of a combined change in place and manner are added to both groups (so the total number is greater than the number of harmonic tokens).

(11) Feature changes





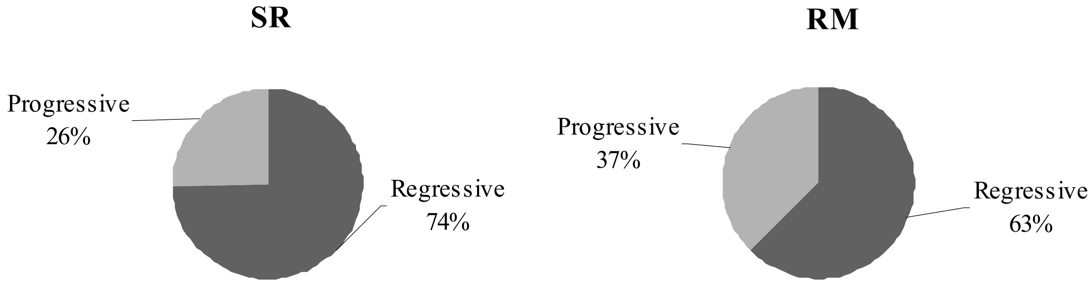
It can be seen that for both children PoA harmony is dominant with respect to MoA harmony, as reported in previous studies (Goad 1997, among others). MoA harmony has high rates as well (cf. Tzakosta 2007) but these come mostly from cases that involve a combined change of place and manner. Presumably, the relatively low rates of pure MoA stems from the fact that most cases of harmonic manner change can be attributed to non-assimilatory substitutions (see (7) and (10)).

5.2 Directionality

Directionality of assimilation is one of the most studied aspects of CH. CH is said to be *progressive* (left-to-right) if the trigger precedes the target (e.g. /pil/ 'elephant' → [pib]), and *regressive* (right-to-left) if the trigger follows the target (e.g. /mig'dal/ 'tower' → [mig'lal]). The proportion of progressive vs. regressive CH can be seen in (12).

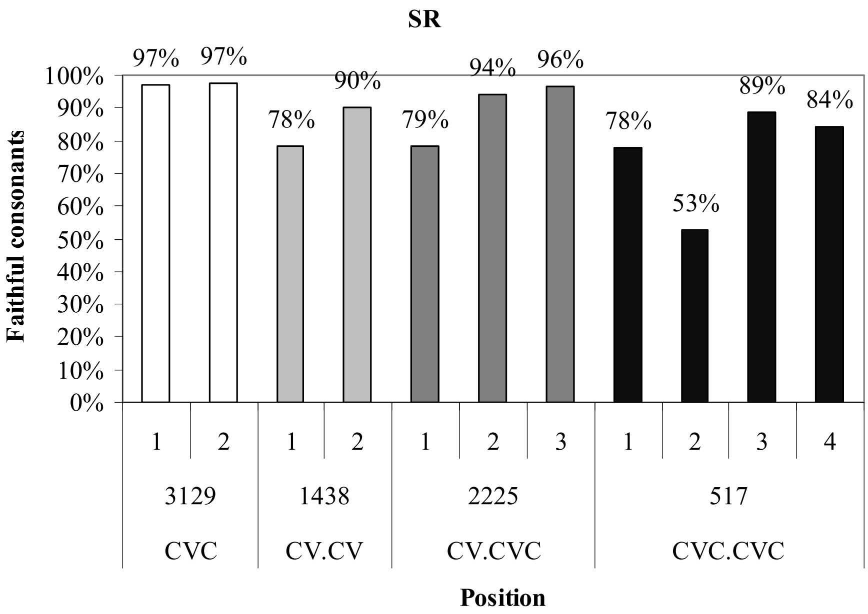
[8] As voice changes seem to occur rather freely for both children I do not refer to such changes as a separate type.

(12) Directionality

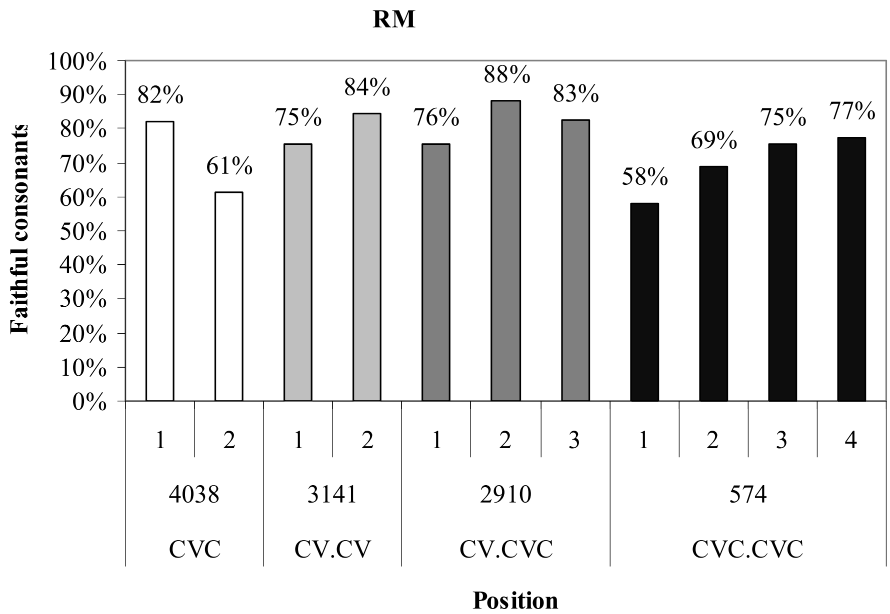


Here we can see again similarity between the children as both prefer regressive to progressive assimilation, in accordance with previous studies (Cruttenden 1978, Vihman 1978, Pater & Werle 2003 among others).[9] A reasonable cause for such a bias is prosodic demands. The charts in (13) show the percentages of faithful productions of consonants in different prosodic positions in the examined corpora (unfaithful productions can be either deletion or substitution). For this illustration I chose words of the following structures: CVC, CV.CV, CV.CVC and CVC.CVC. These structures are relatively common and provide most of the CH examples. The charts are organized by structure and each column represents a certain position. The marking numbers designate the relative position in the word (e.g. column '1' in the CVC group is for the first C and column '2' is for the second C). In addition, the charts indicate the number of examined token words of each structure.

(13) Faithfulness by prosodic positions



9 Regressive CH is also prevalent in adult harmonic systems, a fact that has been attributed to anticipatory effects. The existence of progressive CH in adult systems can be accounted for by other independently motivated factors (Hansson 2001).



When considering prosodic positions in polysyllabic words it is evident that the leftmost positions tend to be less faithful than positions on their right. This finding may suggest that the preference for regressive CH is a consequence of the acquisition process of syllabic structures. In monosyllabic productions (CVC) we see equally faithful productions in both positions for SR, and more faithful onsets than codas for RM. This finding is also compatible with the directionality of assimilation: SR has 10 cases of progressive harmony vs. one regressive case in CVC words. R has 6 progressive cases vs. 6 regressive ones.

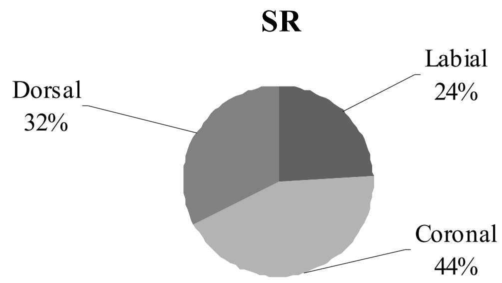
These observations support the findings of Ben-David (2001) regarding both the course of syllable acquisition and directionality of CH in Hebrew. Ben-David reports that in monosyllabic words the onset is produced before the coda, and in polysyllabic words the final syllables are acquired before initial syllables. The acquisition process of syllable types is characterized by harmonization of consonants in newly acquired positions to consonants in well established positions, usually on the right of the new position. A possible reason for this course of development is likely to be the stress pattern in Hebrew (mostly final stress).

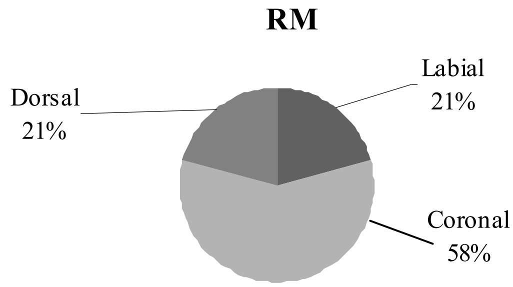
The claim that CH is motivated by prosodic factors is not in consensus. Some studies (e.g. Cruttenden 1978, Pater and Werle 2003) argue that directionality is determined mainly by segmental considerations (i.e. trigger-target hierarchy). Vihman (1978) supports both views and suggests that different children may use CH for different purposes.

5.3 Triggers and Targets

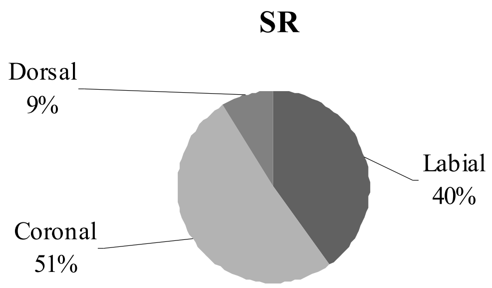
In this section I examine the properties of the consonants involved in the assimilation process (i.e. triggers and targets). Charts (14) and (15) present the PoA distributions of trigger and targets.

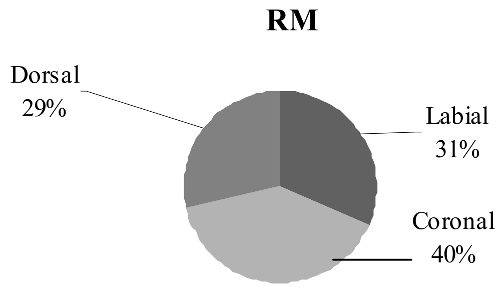
(14) Triggers by Place of Articulation





(15) Targets by Place of Articulation

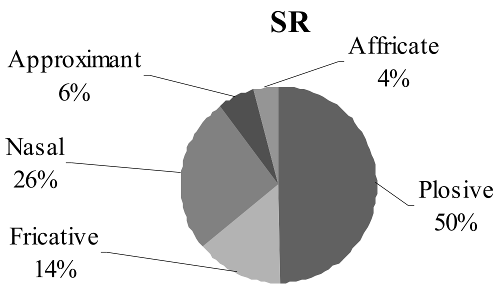


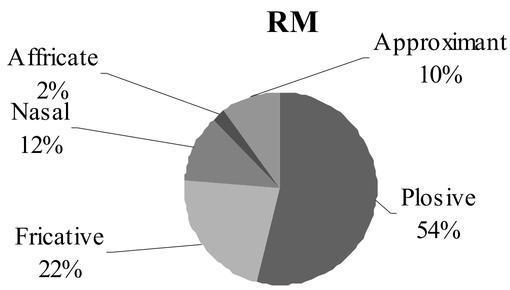


A short examination reveals that both children prefer coronals as triggers of assimilation. The differences between them are mostly quantitative; RM has a stronger bias towards coronals, while SR has a more balanced distribution. Looking at (15) we can see that SR has a clear preference for coronal and labial targets and very low amount of dorsal targets. In contrast, RM has a more balanced distribution with a slight bias towards coronal targets.

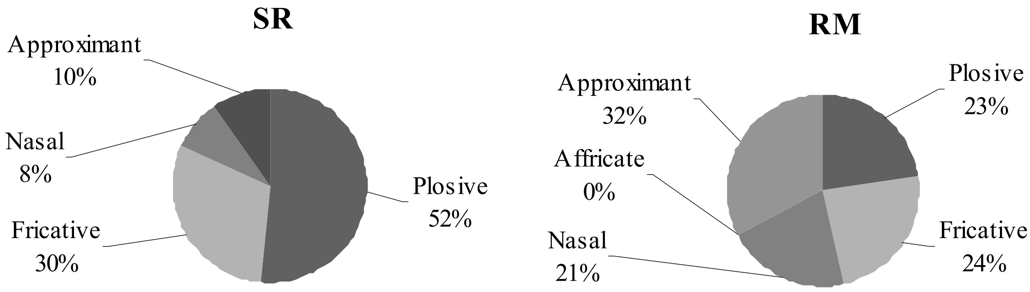
Next, I examine the MoA properties of the triggers and targets. Results are shown in (16) and (17).

(16) Triggers by Manner of Articulation





(17) Targets by Manner of Articulation



Looking at (16) it can be seen that the children have a similar preference ranking of triggers with plosives being the dominant. The only notable difference is the relative abundance of fricative and nasal triggers, where SR shows a bias towards nasals and RM has a bias towards fricatives. With regards to the targets we can learn from (17) that SR has a strong preference for plosive targets and also high rates of fricative targets, while RM has a balanced distribution with a slight preference for approximants.

To summarize, the analysis presented above did not find evidence for a markedness based bias in picking the triggers and targets of CH. For both children, unmarked consonants, i.e. coronals and plosives, seem to be favorable triggers and targets, but marked consonants can also play either role. This is in contrast to some previous studies that attributed the choice of targets to either unmarked segments (e.g. Stoel-Gammon and Stemberger 1994, Pater and Werle 2003) or to marked segments (Tzakosta 2007).

6 Conclusions

In this paper I have examined the status of CH in the phonological development of two typically developing children acquiring Hebrew. The evidence on directionality and lack of clear trigger-target hierarchy suggest that CH is driven mainly by prosodic demands. Segmental factors might also have some influence but they are outweighed by prosodic factors.

The identification process of CH has managed to question the mechanism behind many harmonized productions and leave the impression that CH has a marginal role compare to other processes. Although it is commonly assumed that CH is a part of the child's grammar (i.e. it is driven by explicit demands/constraints favoring harmonic forms), it is at least conceivable that some harmonic forms do not result from a productive harmonic grammar, but rather from random errors, much like slips of the tongue found in adult speech. This idea is supported by the existence of many unique harmonic productions that do not seem to reflect some general properties of the children's grammars at the relevant stage of development.

As this study included only two participants the results cannot be guarantied to hold in general. Future studies will need to rely on subjects that have considerably higher rates of CH in order to reach more definite conclusions. However, I argue that future studies on this subject will suffer from similar limits as the present study due to the difficulty in certain identification of CH.

Appendix A: Examples for different types of substitutions (from both children)

(18) Place

Type		**Harmonic**			**Non-Harmonic**		
Labial	→ Coronal	/pil/	‘elephant’	→ [til]	/ˈpeʁaχ/	‘flower’	→[ˈteʁaχ]
	→ Dorsal	/mesiˈba/	‘party’	→ [ga]	/niʃbeˈʁa/	‘got broke-3SG.FM’	→ [ge'ʁa]
Coronal	→ Dorsal	/ˈtuki/	‘parrot’	→ [ˈkuki]	/tov/	‘good’	→ [koov]
	→ Labial	/ˈʔotobus/	‘bus’	→ [ˈʔopobuθ]	/tut/	‘strawberry’	→ [put]
Dorsal	→ Coronal	/kaˈduʁ/	‘ball’	→ [taˈdu]	/kaf/	‘spoon’	→ [taf]
	→ Labial	/bakˈbuk/	‘bottle’	→ [buup]	/kan/	‘here’	→ [pan]

(19) Manner

Type		**Harmonic**			**Non-Harmonic**		
Plosive	→ Nasal	/baˈnana/	‘banana’	→ [maˈnana]	/baˈtsek/	‘dough’	→ [maˈtsek]
Plosive	→ Fricative	/taˈpuz/	‘orange’	→ [taˈfus]	/paʁˈtsuf/	‘face’	→ [faʁˈtuv]
Coronal Plosive	→ [l]	/migˈdal/	‘tower’	→ [migˈlaal]	/madbeˈka/	‘sticker’	→ [malbeˈka]
/t/ affrication		/maˈtsat/	‘found. 2SG.FM’	→ [maˈtsats]	/bait/	‘house’	→ [baits]
Fricative	→ Nasal	/avaˈnim/	‘stones’	→ [amaˈnim]	/teleˈvizja/	‘television’	→ [teˈvinaa]
Fricative	→ Plosive	/kos/	‘glass’	→ [kot]	[ˈeseʁ]	‘ten’	→ [ˈeteʁ]
Coronal Fricative	→ [l]	/simˈla/	‘dress’	→ [laˈla]	--	--	--
Nasal	→ Plosive	/ken/	‘yes’	→ [ked]	/naˈχaʃ/	‘snake’	→ [deˈχaʃ]
Nasal	→ Fricative	/χaˈmuts/	‘sour’	→ [χaˈvus]	/migˈdal/	‘tower’	→ [viˈgaj]
/n/	→ [l]	/likˈlot/	‘to buy’	→ [likˈlot]	/kaˈtan/	‘small’	→ [ka'taal]
/l/	→ [n]	/χatuˈlim/	‘cats’	→ [χatoˈniim]	/tiˈjul/	‘trip’	→ [tiˈjun]
Approximant	→ Plosive	/gaˈdol/	‘big’	→ [gaˈdot]	/ˈlama/	‘why’	→ [ˈdama]
/l/	→ Fricative	/ʃel/	‘of’	→ [zes]	/pil/	‘elephant’	→ [biʃ]
/ʁ/	→ [χ]	/ʃiʁ/	‘song’	→ [ʃiuχ]	/guʁ/	‘cub’	→ [guuχ]
/χ/	→ [ʁ]	/χaˈseʁ/	‘missing’	→ [ʁaˈteʁ]	/χipuˈʃit/	‘beetle’	→ [ʁepuˈsit]

Appendix B: Harmonic substitutions of specific segments

Type		SR		RM	
		Harmonic	Non-Harmonic	Harmonic	Non-Harmonic
/d/	→ [χ]	—	—	1	0
/f/	→ [t]/[d]	0	2	1	0
/h/	→ [ʁ]	1	0	—	—
	→ [d]	—	—	1	0
	→ [n]	—	—	1	0
	→ [j]	—	—	1	6
/j/	→ [l]	2	1	1	9
	→ [d]/[t]	2	0	11	6
	→ [m]	—	—	1	2
	→ [b]/[p]	—	—	2	2
/k/	→ [θ]/[s]	2	0	0	2
	→ [n]	—	—	3	1
	→ [v]/[f]	2	0	0	1
/l/	→ [v]	1	0	2	0
	→ [ʁ]	4	0	0	3
	→ [g]/[k]	—	—	2	3
	→ [χ]	—	—	1	1
	→ [m]	0	3	2	7
	→ [b]	—	—	1	1
	→ [j]	0	8	7	246
/m/	→ [d]	1	0	2	0
	→ [θ]	1	0	—	—
	→ [g]	2	0	—	—
	→ [z]	—	—	1	0
	→ [χ]	—	—	1	0

/n/	→ [g]	1	0	2	1
	→ [ʁ]	1	0	—	—
	→ [j]	0	1	1	36
/p/	→ [n]	1	0	—	—
/ʁ/	→ [p]/[b]	1	0	3	0
	→ [l]	2	2	1	11
	→ [n]	2	0	1	3
	→ [w]	1	2	0	5
	→ [v]	—	—	1	2
	→ [d]	—	—	9	1
	→ [ʃ]	—	—	2	1
/s/	→ [g]	—	—	1	0
/ʃ/	→ [m]	10	0	—	—
	→ [b]	—	—	1	0
/v/	→ [n]	11	0	—	—
	→ [d]/[t]	—	—	6	0
/χ/	→ [p]/[b]	1	0	0	2
	→ [d]/[t]	—	—	2	3

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