

Tiberian Hebrew Spirantization and Phonological Derivations

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Chomsky (1995) cites Hebrew spirantization as an example of a phonological phenomenon whose conditioning factors are rendered opaque by the operation of later processes in the phonological derivation. Because Optimality Theory (OT; e.g., Prince and Smolensky 1993) is built on surface output conditions (and in more recent versions constraints comparing input and output representations and enforcing uniformity in paradigms), any such cases of intermediate representations raise nontrivial questions for OT. These cases become more interesting and revealing when we try to provide comprehensive OT accounts using the general devices employed in the OT literature. This article examines Tiberian Hebrew spirantization in greater detail and demonstrates that spirantization and related phenomena cannot be adequately handled nonderivationally in OT.

Keywords: phonology, Hebrew, spirantization, derivation, Optimality Theory

1 Introduction

Chomsky (1995:223–224) cites Hebrew spirantization as an example of a phonological phenomenon whose conditioning factors are rendered opaque (even absent) by the operation of later processes in the phonological derivation in standard generative phonology.

My own judgment is that a derivational approach is nonetheless correct, and the particular version of a minimalist program I am considering assigns it even greater prominence, . . . There are certain properties of language, which appear to be fundamental, that suggest this conclusion. Viewed derivationally, computation typically involves simple steps expressible in terms of natural relations and properties, with the context that makes them natural “wiped out” by later operations, hence not visible in the representations to which the derivation converges. . . . In segmental phonology, such phenomena are pervasive. . . . [S]pirantization and vowel reduction are natural and simple processes that derive, say, Hebrew *ganvu* ‘they stole’ from underlying *g-n-B*, but the context for spirantization is gone after reduction applies; the underlying form might even all but disappear in the output, as in *hitu* ‘they extended’, in which only the /t/ remains from the underlying root /ntC/ (C a “weak” consonant).

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Optimality Theory (OT; e.g., Prince and Smolensky 1993, McCarthy and Prince 1993a,b) advocates the complete elimination of phonological rules. OT replaces rules and derivations with a generate-and-test model, in which the candidate surface forms are compared in terms of the degree to which they meet surface output conditions (and in more recent versions of OT input-output and output-output correspondence constraints), as in (1).

- (1) Gen(input) = {candidates}
 Eval({candidates}, {constraints}) = output

Since phonological rules are eliminated, the primary source of derivational steps is eliminated as well. As pointed out numerous times in the OT literature, OT is not logically incompatible with derivational accounts, for the surface forms could be calculated in a series of chained OT calculations. However, the surface orientation of the constraints makes a nonderivational theory practicable and, as Prince and Smolensky (1993:5) argue, desirable.

A contrasting view would hold that the Input $\rightarrow$ Output map has no internal structure: all possible variants are produced by Gen in one step and evaluated in parallel. . . . [W]e will focus predominantly on developing the parallel idea, finding strong support for it, as do McCarthy and Prince [1993b].

Furthermore, the vast majority of OT analyses have assumed parallel, nonderivational calculations. In particular, the OT accounts discussing Hebrew spirantization (Smolensky 1995, McCarthy 1995, Benua 1995) have advocated parallel, nonderivational analyses. For example, McCarthy (1995:3–4) writes (emphasis in the original):

The surface forms evaluated by an Optimality-Theoretic grammar show the effects of various phonological processes *in parallel*; there is no serial derivation. . . . In OT . . . there is no serial derivation; rather, the surface form is determined by evaluating the effects of all phonological alternations simultaneously.

Thus, because OT is built on the parallel evaluation of surface candidates in terms of their adherence to surface-oriented constraints, any case requiring intermediate representations raises a non-trivial question to be addressed and analyzed.

The best way to address this question is to examine the OT accounts that have been proposed for Hebrew spirantization (and any enhancements that might be offered for such analyses) and to examine the consequences for OT imposed by such solutions. I will attempt to do this here. I will not construct a substantial partial OT grammar for Tiberian Hebrew, but I will assume that constraints can be formulated and ranked to generate the surface patterns for processes other than spirantization, though many other opaque rule interactions exist in rule-based accounts such as Prince 1975 (e.g., the relations between Pretonic Lengthening, Schwa Deletion, and Tonic Lengthening). The surface orientation of OT constraints allows us to be somewhat agnostic about how the rest of the constraints are formulated and ranked, since the constraints should be in terms of surface properties, or input-output relations.

My conclusion is that all proposed OT solutions to Hebrew spirantization are inadequate and that even extensive modifications to the analyses will not yield satisfactory accounts. In

particular, attempts to formulate constraints to handle Hebrew spirantization along the lines of Smolensky 1995 (in the version of OT presented in Prince and Smolensky 1993) lead to paradoxes of parsing and visibility. The paradox is that spirantization is conditioned prosodically (by a preceding nucleus), but some of the relevant vowels are not present phonetically. Since phonetic absence (deletion) is handled in Prince and Smolensky 1993 by a stray erasure convention applying to unparsed elements, this constitutes a paradox, for the vowel must be parsed in order to correctly condition spirantization, but must *not* be parsed in order to be absent phonetically.

Correspondence theory accounts such as McCarthy 1995 and Benua 1995 suffer from different inadequacies. As it stands, the spirantization account offered in McCarthy 1995 cannot handle imperfective verb forms. I consider various possible modifications, such as output-output (or paradigm) constraints, but none turn out to be satisfactory. I conclude that the various extant versions of OT cannot provide a unified nonderivational account of Hebrew spirantization, confirming Chomsky's remarks.

2 Hebrew Spirantization Facts

Nonemphatic stops alternate with fricatives in Hebrew. Alternations such as those in (2) (adapted from McCarthy 1979) are typical.

- (2) a. [t ~ θ, k ~ x] ka:θáv 'write 3MS PERF' Josh. 8:32
 yixtó:v 'write 3MS IMPF' Isa. 44:5
 b. [g ~ γ, d ~ ð] ga:ðlú: 'be great 3P PERF' Jer. 5:27
 yiydá:lu: 'be great 3MP IMPF' Ruth 1:13

The basic generalization is that fricatives appear postvocally and stops appear elsewhere (post-consonantly and at the beginning of words following pause).

Tiberian Hebrew had the consonant system in (3) (Prince 1975:8–9).¹ Stop-spirant pairs in the obstruent series are paired vertically.

- | | |
|---------------------------|---------------------|
| (3) <i>Obstruents</i> | <i>Sonorants</i> |
| p b t ḏ ṣ z š (ś) š k g q | m n l r y w ḥ ʕ h ? |
| f v θ ð | x γ |

The set of alternating stop-spirant pairs has changed through the centuries, with Tiberian Hebrew having stop-spirant pairs for all nonemphatic stops and Modern Hebrew having only a subset of the stop-spirant pairs: [p~f], [b~v], [k~x]. This article will be concerned only with the spirantization facts of Tiberian Hebrew. A theoretical examination of Modern Hebrew and the historical development of spirantization is offered in Idsardi 1997a.

¹ *Tiberian Hebrew* is the term used for the language of the version of the Hebrew Bible as annotated by the Masoretes. The examples in this article are drawn both from previous generative studies (e.g., Prince 1975, Malone 1976, 1989, 1993, McCarthy 1979, Dresher 1983, Rappaport 1985) and from standard references (Brown, Driver, and Briggs 1906, Gesenius 1910, Joüon 1991, and Weingreen 1959). Biblical citations are principally from Kohlenberger 1987. Computer searches were done on the Davka Corporation CD-ROM Bible and the Michigan-Claremont computerized version of the Biblia Hebraica Stuttgartensia, which is available from the Center for the Computer Analysis of Texts at the University of Pennsylvania.

Although spirants usually appear following a surface vowel, there are a number of complications to this generalization. The range of environments in which spirants appear is given in (4).²

(4) Spirants occur

- a. after vowels present at both underlying representation (UR) and surface representation (SR) (as in (2))
- b. after some vowels present at UR but not at SR
(deleted vowels; compare (5f))
/katab + u/ → [ka:θvú:] ‘write 3P PERF’ Ezra 4:6
compare /katab/ → [ka:θáv] ‘write 3MS PERF’ Josh. 8:32
- c. after vowels present at SR but not at UR (epenthetic vowels)
/malk/ → [mélex] ‘king’ Gen. 14:1
- d. between words in the same phrase
[wayyaʕālú: yē:θ-ʔé:1] ‘and go up 3MP IMPF Bethel’ Judg. 20:18
- e. after a vowel when an intervening syllable-final laryngeal is deleted
/ya-ʔakal/ → [yo:xál] ‘eat 3MS IMPF’ Gen. 49:27³
[ma:ʕá:(ʔ)θi:] ‘find 1S PERF’ 1 Kings 21:20
[he:ví:(ʔ) yam] ‘bring (come) 3MS PERF Hiffil also’ Gen. 4:4
[ʔim-ʔemʕá:(ʔ) yisdó:m] ‘if find 1S IMPF in Sodom’ Gen. 18:26
[wattəmalle:(ʔ) xaddá:] ‘and fill 3FS IMPF jar FS’ Gen. 24:16
- f. across the glides /y w/
[ħa:yθá:] ‘live 3FS PERF’ Gen. 12:13
[ħa:yθá:] ‘be 3FS PERF’ Ezek. 21:17
[wəra:yθá:] ‘quench-thirst 3FS PERF’ Jer. 46:10
[hammá:wθa:] ‘death DIR’ Ps. 116:15
[báyθa:] ‘house DIR’ Ps. 68:7
[me:ʔo:yví:m] ‘from enemy PL’ Ps. 68:24
[ħəzayθá:] ‘see 2MS PERF’ Dan. 2:41
[ʕa:wθá:] ‘do wrong 3FS PERF’ Esther 1:16
one exception: [ša:láwti:] ‘be tranquil 1S PERF’ Job 3:26
- g. with degeminated consonants
/rabb/ → [rav] ‘great, much MS’ Gen. 24:25
compare /rabb-im/ → [rabbí:m] ‘many MP’ Num. 20:11
- h. in both onsets and codas
[ka:θáv] ‘write 3MS PERF’ Josh. 8:32

It is particularly important to notice that the occurrence of spirants is not predictable from the surface syllabic position of the consonant. Spirants occur both as codas and as onsets. The condi-

² Underlining is used only to mark the segments of interest, not to indicate spirant pronunciation.

³ Not all stem-initial /ʔ/ verbs behave this way. Others retain the vowel following /ʔ/ as a hateph vowel.

tioning factor is rather the adjacency to a preceding nucleus, not the syllabic affiliation of the segment in question.

However, even though spirants occur in all of the positions catalogued in (4), spirant members of stop-spirant pairs are banned from other environments, catalogued in (5).

- (5) Spirant realizations of stop-spirant pairs do not occur
- a. after a pause
 - b. after consonants (except (4b) and (4f) cases)
 - c. with surface geminates (compare (4g))
 - underlying /rabb-im/ → [rabbí:m] ‘many MP’ Num. 20:11
 - derived /ya-n-kateb/ → [yikka:θé:v] ‘write 3MS IMPF Nifʿal’ Esther 8:5
 - d. across gutturals (compare (4f))
 - [ʔaʕí:r] ‘pray 1S IMPF Hifʿil’ Exod. 8:5
 - [wənaʕtót:r] ‘and pray INF Nifʿal’ 1 Chron. 5:20
 - [wənaʕbərá:] ‘go over 1P IMPF COHOR’ 1 Sam. 14:1
 - [yaḥbót:t] ‘strike 3MS IMPF’ Isa. 27:12
 - [yirdót:f] ‘pursue 3MS IMPF’ Deut. 32:30
 - exceptionally undeleted syllable-final laryngeals act similarly:
 - [wayyeʔpót:ð] ‘and surround 3MS IMPF’ Lev. 8:7
 - [yehdót:f] ‘push 3MS IMPF’ Prov. 10:3
 - e. when “metathesized” into postconsonantal position
 - [ləhiʕtabbéaḥ] ‘praise INF Hitpaʿel’ Ps. 106:47
 - [me:histappéaḥ] ‘from share GERUND Hitpaʿel’ 1 Sam. 26:19
 - compare [wəhiθba:ré:x] ‘and bless 3MS PERF Hitpaʿel’ Deut. 29:18
 - f. after a deleted vowel following a prefix (compare (4b))
 - /ya-katob/ → [yixtót:v] ‘write 3MS IMPF’ Is. 44:5
 - /na-katab/ → [nixtáv] ‘write 3MS PERF Nifʿal’ Esther 8:8
 - compare /katab-u/ → [ka:θvú:] ‘write 3MS PERF’ Ezra 4:6
 - where the deleted vowel is later in the stem
 - and /b#katob/ → [bixθót:v] ‘when writing’ Ps. 83:6
 - where the deleted vowel follows a proclitic
 - g. following a word ending in a glide (compare (4d,f))
 - [waysáw dā:wí:ð] ‘and order 3MS JUSS David’ 1 Chron. 22:17

There are also other spirants that do not alternate with stops (e.g., [s]). These fricatives can occur in all of the relevant phonetic environments listed above.

Most previous analyses have taken the underlying forms to be stops, deriving the spirant (continuant) realizations by rule; one exception is Elmedlaoui 1993. One reason for postulating underlying stops is the universal tendency of languages to have underlying stops in preference to fricatives. Another reason is that the class of surface continuants also includes [s š], which are not paired with stops. The best alternative that combines all of these insights is to not include any value for [cont] in the underlying representations for the stop-spirant pairs, and to supply the

value for [cont] in the phonological calculation. This is in essence the type of analysis employed in Chomsky 1951.

The crucial test case for any theory of spirantization is the difference in behavior between (4b) and (5f), for together they show that spirantization does not uniformly occur following all deleted vowels. Because these cases are so crucial, it will be necessary to briefly review the morphology of the verb stem in Hebrew.

The perfect, imperfective, and intensive perfect (*Piʕel*) forms for the verb root /ktb/ ‘write’ are shown in (6). Sound trilateral verb stems can show four different surface shapes: CVCVC, CVCCVC, CVCC, and CCVC. Vowel length is phonologically predictable, and there are different agreement markers for the perfective and imperfective aspects.

(6)	<i>Perfective</i>		<i>Imperfective</i>		<i>Piʕel perfective</i>	
1S	ka:θáv-ti:	CVCVC	ʔe-xtó:v	CCVC	kittáv-ti	CVCCVC
2MS	ka:θáv-ta:	"	ti-xtó:v	"	kittáv-ta:	"
2FS	ka:θáv-t	"	ti-xtəv-í:	"	kittáv-t	"
3MS	ka:θáv	"	yi-xtó:v	"	kittév	"
3FS	kəθav-á:	CVCC	ti-xtó:v	"	kittəv-á:	"
1P	ka:θáv-nu:	CVCVC	ni-xtó:v	"	kittáv-nu:	"
2MP	kəθav-tém	"	ti-xtəv-ú:	"	kittav-tém	"
2FP	kəθav-tén	"	ti-xtó:v-na:	"	kittav-tén	"
3MP	ka:θv-ú:	CVCC	yi-xtəv-ú:	"	kittəv-ú:	"
3FP	ka:θv-ú:	"	ti-xtó:v-na:	"	kittəv-ú:	"

McCarthy 1979 represents a watershed in the analysis of stem-shape patterning in Semitic morphology. Previous accounts, such as Prince 1975, had tried to build stem shapes from an underlying CVCVC form through morphophonological rules of deletion and insertion. McCarthy suggested instead that the stem shape is supplied morphologically for the particular binyan and aspectual class, with the root consonants then associating to the template. In the case of the CVCC stems, however, McCarthy also derived this stem shape from /CVCVC/ with a phonological rule of vowel deletion. More recently, McCarthy and Prince (1990), McCarthy (1993b), and Dobrin (1993) have argued for a return to the idea that *all* verb stem shapes are based on a CVCVC stem. They argue that the stem shapes CCVC, CVCC, and CVCCVC must be derived through morphophonological processes because these shapes do not define valid prosodic constituents and therefore they are incoherent from the standpoint of Prosodic Morphology. For example, the first C in the CCVC case is syllabified not with the stem but with the preceding prefix. Therefore, the prosody of a stem exhibiting this shape is a mora plus a syllable, [μ σ], which is not a valid prosodic constituent. The shape CVCCVC is also incoherent, they argue, because it is not a valid foot type, being too large to be either a trochee or an iamb. McCarthy and Prince (1990) derive the CVCCVC shape by infixing a prosodic position (a mora) after the first syllable of the CVCVC stem. The CCVC case is handled in Arabic by a phonological rule of vowel deletion (McCarthy 1993b:202). Rappaport (1985) likewise argues that the Hebrew imperfective CCVC shape arises from a phonological process of vowel deletion. For the correct surface forms (including spirantiza-

tion) to be generated in the Hebrew case, however, prefixed stems must undergo two levels of calculation, both cyclic and noncyclic (see Rappaport 1985 for details). The existence of the cyclic level is crucial in capturing the difference in spirantization of consonants following deleted vowels; compare [yix-to:v] ‘write 3MS IMPF’ with [ka:θ-vu:] ‘write 3MS PERF’. No spirantization occurs with the /t/ following the deleted vowel in the imperfective, but the spirant [v] does occur following the deleted vowel in the perfective. Any analysis of spirantization must capture this distinction. In Rappaport’s derivational analysis (carried over into the present article) this is accounted for by deleting the vowel in the imperfective in the cyclic stratum, while deleting the vowel in the perfective noncyclically; see the next section for details.

3 A Rule-Based Analysis

To account for the generalizations in (4) and (5), the rule-based analysis (combining insights from Chomsky 1951, Prince 1975, Rappaport 1985, and Malone 1993) orders the spirantization rule among other morphophonological rules. A partial grammar is shown in (7). Of course, there are other morphological and phonological rules in Tiberian Hebrew; see especially Prince 1975, Dresher 1983, Rappaport 1985, and Malone 1993 for examples and analyses. The summary of rules in (7) is limited to those rules that interact relatively directly with spirantization.

- (7) Morphology: Medial Gemination
 Hitpaʕel Formation
 Phonology: Cyclic: Vowel Reduction
 Schwa Deletion
 Closed-Syllable *i*
 n-Deletion
 Noncyclic: Gemination
 Pretonic Lengthening
 Laryngeal Deletion
 Compensatory Lengthening
 Vowel Reduction
 Word-Final Degemination
 Spirantization
 Schwa Deletion
 Closed-Syllable *i*

Very few rules apply cyclically in Tiberian Hebrew. The ordering of the rules that do apply cyclically is consistent with the more general order established for the noncyclic block. This suggests that the rules are mentally arranged in a single list, each rule being annotated for the stratum or strata in which it applies.

- (8) a. Gemination (noncyclic)
 b. Pretonic Lengthening (noncyclic)
 c. Laryngeal Deletion (noncyclic)

- d. Compensatory Lengthening (noncyclic)
- e. Vowel Reduction (cyclic and noncyclic)
- f. Word-Final Degemination (noncyclic)
- g. Spirantization (noncyclic)
- h. Schwa Deletion (cyclic and noncyclic)
- i. Closed-Syllable *i* (cyclic and noncyclic)
- j. *n*-Deletion (cyclic)

This model of the organization of the phonological grammar then predicts that two rules cannot be ordered differently in different strata. I know of no counterexamples to this claim.

The morphological component is responsible for constructing the underlying representations for the phonological component. In the case of Tiberian Hebrew, the rules relevant for spirantization are the limited infixation of /t/ in the Hitpaʕel (commonly analyzed as metathesis) and the construction of stem forms by infixation (Medial Gemination) and vowel deletion (the CCVC stem shape characteristic of the imperfective tenses). Assuming that syllable structure is encoded in the basic template form (and therefore is visible in the morphology), the rules are then as in (9).

- (9) a. *Medial Gemination*
 $\emptyset \rightarrow x / [\text{piʕel, etc.} [\text{CV} \text{ — } \sigma]]$
- b. *Hitpaʕel Formation*
- i. $\emptyset \rightarrow x / [\text{Hitpaʕel } x \text{ —}]$

$\begin{array}{c} | \qquad \diagup \quad \diagdown \\ [-\text{son}] \quad [-\text{son}] \text{ Coronal} \end{array}$
 - ii. $\emptyset \rightarrow /t/ / [\text{Hitpaʕel} \text{ —}]$

If the Hitpaʕel infixation, (9bi), applies, then all Guttural features spread rightward from the stem-initial consonant. As a result, the infix agrees in voicing and [RTR] (emphasis) with the stem-initial segment. As noted by Gesenius (1910:149), the Hitpaʕel of some stems beginning with /n/, /k/, or /t/ is exceptionally formed through infixation. The infixation is also more general in other Semitic languages.

The bleeding of Spirantization in the Medial Gemination and Hitpaʕel “metathesis” cases (5g) is an example of the familiar situation of a morphological rule applying prior to a phonological rule. Thus, this relationship is the expected one in standard generative phonology.

As discussed above, the appearance of the short stem shapes CCVC and CVCC is governed by the operation of the rules of Vowel Reduction and Schwa Deletion on the base stem shape CVCVC. This is uncontroversial in the case of CVCC stems with vowel-initial suffixes (such as [ganvu], above). In the case of CCVC stems, these occur in certain morphological circumstances, such as the Qal imperfective and the Nifʕal perfective. However, no generalization in terms of morphological features is possible that would include just the relevant morphological categories. As discussed in Prince 1975 and Rappaport 1985, the relevant generalization is a morphophonological one; it is those verbs that contain a (light) prefix. This is handled by subjecting any prefix-stem combination to the cyclic block of rules. Notably, unprefix-stems are not subject to the

cyclic rules. To correctly model imperative and infinitive construct forms (see below), we will assume that these forms do contain a prefix, but that this prefix is $\emptyset$ - (zero) in the Qal and Piʿel imperatives and in all infinitive constructs. This is similar to the account in Rappaport 1985, but modified along the lines of Noyer 1992. Then the generalization can be handled as follows: all verb prefixes are cyclic, and everything else in the verbal system (stems, suffixes, enclitics, and proclitics) is noncyclic (except for the [+cyclic] proclitic /l#/; see below). Then, in cases where no prefixes are present, there is no cyclic calculation.

Hebrew syllables are limited to one onset consonant and one coda consonant. Vowels inserted for the purposes of syllabification are not projected onto the grid and are therefore metrically invisible. This explains the surface opacity of the segholate stress patterns, as in [mélex] ‘king’, (4c). Note that the epenthetic vowels do trigger spirantization.

The environment for Vowel Reduction is calculated metrically, as described in Rappaport 1985 and Halle and Vergnaud 1987. Binary feet are constructed from right to left, with the proviso that heavy syllables must end feet. In the stress theory developed in Idsardi 1992 and Halle and Idsardi 1995, this is handled by the rules in (10a) and (10b). Vowel Reduction then eliminates a grid mark from the vowel, as in (10c), which is also the formal mechanism implementing stress shift. Notice that the environment for the operation of the rule is a branching foot (the absence of an intervening foot boundary being significant). This ensures that reduction takes place only in open syllables.

- (10) a. *Heavy Syllable Marking*
 Project) for bimoraic syllables.
 b. *Iterative Constituent Construction*
 Insert (from right to left.
 c. *Vowel Reduction*
 $\ast \rightarrow \emptyset / (\text{ } ______ \ast$

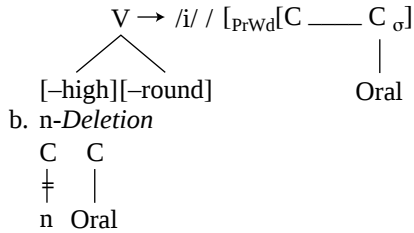
Vowel Reduction feeds the deletion of a reduced vowel (i.e., one without a grid mark) in an open syllable when the onset is not a guttural and the preceding syllable is also open, (11).

- (11) *Schwa Deletion*

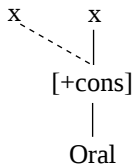
$$\begin{array}{c} V \rightarrow \emptyset / V_{\sigma} [C \text{ } ______ \sigma] \\ | \\ \text{Oral} \end{array}$$

The nonguttural condition is somewhat variable, as is the related process of postguttural epenthesis. I will ignore these complications in this article.

After Schwa Deletion (and consequent resyllabification), when an /a/ or /ə/ is in an initial syllable closed by a nonguttural, it raises to /i/, (12a). Subsequently, in the cyclic block, preconsonantal /n/ is deleted, but the timing slot is retained, (12b). There are a number of lexical exceptions to this rule, but it applies uniformly with the Nifʿal prefix /n-/, as in (5c). Stem-final /n/ is not deleted (except with the root /ntn/ ‘give’); this is correctly captured by restricting the rule to the cyclic stratum.

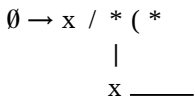
(12) a. *Closed-Syllable* i

In the noncyclic block of rules, Gemination (13) spreads a nonguttural consonant leftward to fill an empty timing slot. This rule is fed by (9a) and (12b), yielding, for example, stem-initial geminates in the Niffal imperfective.

(13) *Gemination*

Since guttural consonants do not geminate, rule (13) is restricted to consonants with an Oral Place articulation (McCarthy 1994, Rose 1996; equivalent to Place in Halle 1995).

Pretonic Lengthening (14) inserts a timing slot in an open syllable before main stress. The absence of a right metrical boundary ensures that the target syllable is light.

(14) *Pretonic Lengthening*

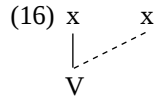
Laryngeal Deletion (15) deletes /ʔ/ in syllable coda position, but leaves the timing slot behind.

(15) *Laryngeal Deletion*

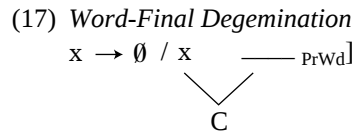
Recall that syllable-final /ʔ/ is not deleted in certain rare cases, such as [wayyeʔpó:ð] ‘and surround 3MS IMPF’ Lev. 8:7, and that in such cases a following stop is not spirantized. These cases show that spirantization is not translaryngeal. Additional support for this analysis is provided by cases in which syllable-final /h/ is retained, such as [yehdó:f] ‘push 3MS IMPF’ Prov. 10:3, and cases of furtive pataḥ and mappiq, which never allow spirantization of an initial /b d g p t k/ of the following word.

Empty timing slots present at this point in the derivation are filled by spreading the preceding vowel, (16). These can include timing slots inserted morphologically when they occur before

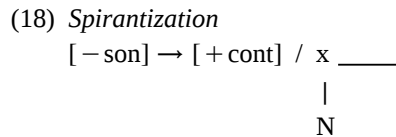
gutturals (in other words, cases failing Gemination) and those arising from Pretonic Lengthening and Laryngeal Deletion.



Word-Final Degemination (17) must precede spirantization to account for words such as [rav] ‘great’, (4g).



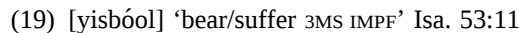
The spirantization rule is given in (18). Obstruents become [+cont] following a nuclear segment, agreeing with the findings of Schein and Steriade (1986).



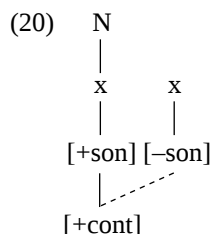
The range of environments for spirantization catalogued in (4) has led Malone (1976, 1993) to classify Spirantization as a ‘persistent’ rule in the sense of Chafe (1968) (see also Myers 1991), applying throughout the derivation whenever its environment is met. However, Prince (1975) showed that there is a place for a single application of spirantization in the serial derivation once vowel deletion is split into two phases: reduction to schwa and schwa deletion (see Prince 1975 for further supporting evidence for this division of vowel deletion into two stages). In the present account these are the two rules (10) and (11). Spirantization then applies noncyclically between these two rules.

The restriction of spirantization to nongeminate stops has been the source of much discussion in the literature (e.g., Hayes 1986, Schein and Steriade 1986). The present account follows Schein and Steriade in the formulation and interpretation of the rule with respect to geminates. Also, because Spirantization is defined as postnuclear, it is intrinsically ordered after the syllabification rules, which provide syllable structure.

Spirantization has been formulated in (18) as the introduction of a [+cont] feature. Another possible view is that spirantization is instead assimilation, the sharing of [+cont]. However, there are several reasons to favor (18). The immediate problem is that underlyingly [+cont] segments do not trigger spirantization of adjacent stops, as shown by (19).



Therefore, to exclude spirantization following /s/, the proposed assimilation rule must include other conditions. But the simplest condition is to require that the triggering item belong to the preceding nucleus, as shown in (20).



Since (20) cannot be simply formulated without reference to the nucleus, it is clear that (20) is no simpler than (18). In fact, (18) is simpler than (20) because the structural description of (18) does not need to specify the nucleus as [+cont].⁴

Additionally, Halle (1995) argues that the feature [cont] is limited to [+cons] segments. And even if we allow specification of [cont] for [−cons] segments, the feature specification [+cont] is redundant for vowels. Therefore, in order to spread the feature [+cont] from a preceding vowel, we will first have to supply the default [+cont] feature on the vowel. But if we want the spreading process to be feature-filling, then we will have to apply spreading before adding the default [−cont] to obstruents. Therefore, the spreading analysis of spirantization would require the default insertion of [+cont] for vowels before spirantization, and the default insertion of [−cont] after spirantization. Rule (18), on the other hand, allows all the default specifications for [cont] to take place uniformly after spirantization, and allows for Halle's stronger interpretation of the restrictions on [cont] that vowels are unspecified for [cont] throughout the phonology. Finally, sharing [+cont] implies that the same stricture gesture is performed in both the vowel and the consonant. But it is clearly possible for different articulators to be active, as in [rav], where the major constriction in [a] is pharyngeal and the major constriction in [v] is labial. True assimilation processes involve articulator-bound features in Halle's (1995) terms and result in one stricture gesture prolonged in time. Clearly, in [rav] two distinct stricture gestures must be performed, and therefore it is a false economy to try to share [+cont] between the vowel and the spirant. Therefore, since the spreading analysis is not supported by phonetic considerations, results in a more complicated system of defaults, and is formally more complicated, I will choose (18) for the remainder of the analysis.

Now consider the analysis of (4f), spirantization occurring across glides. Malone (1976) notes that spirantization is allowed (variably) across /y/ and /w/, but not across the other glides /ʔ ʕ h ɣ/. Prince (1975) sees the matter somewhat differently, offering an account whereby /y w/ themselves trigger spirantization. Prince's account can be easily adapted to current feature theories. In the feature geometries proposed by McCarthy (1994), Halle (1995), and Rose (1996), the glides that trigger spirantization, /y w/, are distinguished from those that do not, /ʔ ʕ h ɣ/, in that /y w/

⁴ A referee suggests that Archangeli and Pulleyblank (1994) indicate that "spread[ing] rules are simpler than feature insertion rules." Archangeli and Pulleyblank (1994:286) formulate both spreading and feature insertion as insertion rules, varying on the Type parameter, Path versus F-element. They do say (p. 367), "... Path rules are less marked than F-element rules..." This is obviously at odds with the characterization of the rules in terms of structural descriptions and changes. Being at a loss to resolve this question, I am resolved to leave it without any resolution.

contain an Oral Place node, whereas the others do not. Thus, the rule (21) could instead be proposed.

$$(21) [-\text{son}] \rightarrow [+ \text{cont}] / [-\text{cons}] \text{ ______ } \\ | \\ \text{Oral}$$

However, Malone (1976) offers a different insight into the difference between the glides that allow spirantization and the other glides: “The true reason . . . is almost certainly that semivowels share certain relevant properties with vowels which other glides do not” (p. 255). Again, we can recast this as follows: those glides that could be syllable peaks allow spirantization. That is, it is potential syllabicity that /y w/ share with vowels. We can identify potential syllabicity with incorporation into the syllable nucleus. That is, we can restrict membership in the nucleus to vowels and /y w/ (that is, to [-cons] items with Oral Place nodes as discussed above) and then retain rule (18). One argument for (18) can be made from consideration of geminates. To adopt Schein and Steriade’s (1986) proposal regarding geminates, we must use the formulation in (18) because (21) makes no reference to the timing tier and thus cannot distinguish between singly-linked and multiply-linked structures. Another argument for (18) is provided by the fact that the two spirantization environments (4d) (between-word) and (4f) (postglide) cannot in general be combined. This fact also provides support for continued word-final extrasyllabicity. Gesenius (1910:75) notes only three examples of between-word spirantization across a glide: [qaw θó:hu:] ‘measuring line-of chaos’ Isa. 34:11, [ʔǎðo:ná:y vá:m] ‘Lord in-them’ Ps. 68:18, and [ha:mó:n ša:lé:w ya:h] ‘crowd carefree around-her’ Ezek. 23:42.⁵ The usual case is amply represented by the instances of the tetragrammaton representing [ʔǎðo:ná:y] ‘Lord’ followed by stops (e.g., Gen. 6:5,6 and hundreds of other cases) and by cases such as [wayšáw ða:wí:ð] ‘and order 3MS Juss David’ 1 Chron. 22:17. An explanation for this is given by the continued extrasyllabicity of word-final consonants, so that word-final /y w/ are not incorporated into the nucleus.⁶ Then a following stop will not be postnuclear and consequently will not undergo spirantization. The nonspirantization between words after a glide receives no simple explanation under rule (21).

Next, let us consider a minor improvement to the rule-based analysis. The analysis can be improved somewhat if we view spirantization as adding both aspiration, [+spread glottis], and [+cont]. The reciprocal reinforcement of [+cont] and [+spread glottis] (enhancement in the sense of Stevens and Keyser 1989) is observable in other languages—for example, in the change of aspirated stops to fricatives in the history of Greek. Laryngeal/[cont] enhancement interactions are investigated in Rice 1994, and Laryngeal-manner interactions generally are taken up in Rice and Avery 1989 and Rice 1993.

The formulation of spirantization as involving the introduction of [+spread glottis], when combined with recent theories of feature geometry for guttural consonants (McCarthy 1988, 1994,

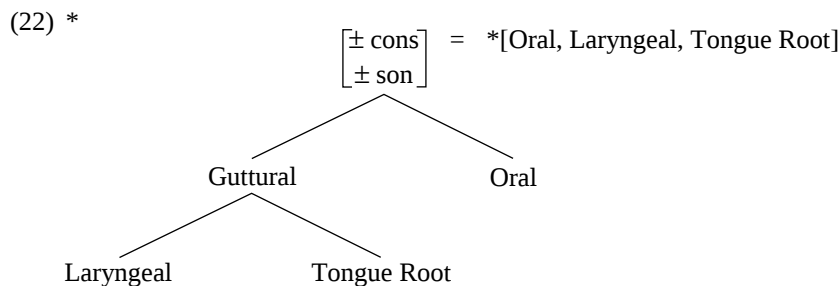
⁵ There is also one case of between-word spirantization across /ʕ/, [ra:šá:ʕ yaʕšawono:] ‘wicked-man for-sin-of-him’ Ezek. 33:8.

⁶ This analysis requires Laryngeal Deletion to be generalized so as to delete word-final as well as syllable-final /ʔ/.

Trigo 1991, Halle 1995, Rose 1996), also allows a simple explanation of the restrictions on spirantization in Tiberian Hebrew. The crux of the matter is the unified behavior of the emphatics, gutturals, and geminates in rejecting spirantization. Combining current theories of feature geometry with some ideas in Prince 1975:11–12, quoted here, leads to a satisfactory account.

Recall that Korean has a three-way distinction of consonant-types into aspirated, non-aspirated and “fortis.” Kim 1970 shows that any geminates arising through morphological combination become “fortis.” This suggests the possibility that Hebrew geminates are “fortis,” that the emphatics are “fortis” as well, and that spirantization does not apply to “fortis” consonants. Now, Kim identifies “fortis” with glottalization, i.e. the feature specification [+ Constricted Glottis, – Spread Glottis], and it may be that the Hebrew geminates should be glottalized by a phonological rule. But “fortis” cannot be simply identified with “emphatic”: the sequence -tt- is never written -ṭṭ-; nor is -kk- written -q- or -qq-. So it seems that the secondary articulation of /t̚ ʃ/ is something other than “fortis” or [+ C.G.]. . . . Assuming glottalization of geminates, the class of segments which spirantize post-vocally can be characterized as [– son – low – C.G.], taking [+ low] (perhaps better is [+ C.P.]) as the feature shared by /t̚ ʃ q/.

If we make the additional assumption that spirantization is in part [+ spread glottis], then the pieces fit together, as follows. The emphatics and gutturals are specified [+ RTR], and in the case of glottal stop [+ constricted glottis]. The restriction on Spirantization is a simple limit on the complexity of the Guttural articulation of any segment. If multiple Guttural articulations are banned, then Spirantization will be blocked from applying to emphatics and glottal stop. However, the constraint cannot exclude two laryngeal features together, because voiced spirants are acceptable. The correct constraint is to disallow the combination of Tongue Root, Laryngeal, and Oral Place nodes, as in (22).



Thus, Laryngeal and Tongue Root are allowed together only without Oral Place, /ħ ʕ/; Place is allowed with Tongue Root (emphatics), but then laryngeal distinctions are neutralized (there are no voicing distinctions); and Oral Place is allowed with Laryngeal (voiced and voiceless stops; spirants by hypothesis). Thus, the constraint (22) serves as an overall inventory restriction in Hebrew, throughout the phonology and phonetic implementation. Thus, it also functions to limit the application of Spirantization.

Now let us return briefly to the question of nonspirantization of geminates. Instead of Schein and Steriade’s (1986) rule application convention, we could adopt Prince’s (1975) suggestion that geminates are [+ constricted glottis]. Then they will be incompatible with [+ spread glottis], as

is the case with /ʔ/,⁷ and will resist Spirantization.⁸ However, this solution does require that the rule glottalizing geminates precede Spirantization, and I can discern no general principles that would predict this ordering. One last explanation might be that geminates are systematically immune because of the “release” nature of [+spread glottis] in Steriade’s (1994) terms, and the fact that Spirantization’s focus is the first half of a geminate, a position that under Steriade’s account systematically lacks a release node.

Some sample derivations are shown in (23).

(23) Morphology	[[ya-katob _{cyc}]-u _{non}]	[katab-u _{non}]	[b#(θ-katob _{cyc})] _{non}]
Cyclic	yakatob	n/a	katob
Vowel Reduction (10c)	x (x (ya)(ka)(to)b		(x (ka)(to)b
Schwa Deletion (11)	x (x (yak)(to)b		
Closed-Syllable <i>i</i> (12a)	x (x (yik)(to)b		
Noncyclic	x (x x (yik)(to)(bu)	x (x x (ka)(ta)(bu)	(x (bə)(ka)(to)b
Vowel Length (14)–(16)		x)(x x (ka:)(ta)(bu)	
Vowel Reduction (10c)	x (x (yik)(to)(bu)	x)(x (ka:)(ta)(bu)	
Spirantization (18)	x (x (yix)(to)(vu)	x)(x (ka:)(θa)(vu)	(x (bə)(xa)(θo)v
Schwa Deletion (11)		x)(x (ka:θ)(vu)	(x (bəx)(θo)v
Closed-Syllable <i>i</i> (12a)			(x (bix)(θo)v
Other rules	[yixtəvú:]	[kà:θvú:]	[bixθó:v]

To summarize, neither the underlying nor the surface level is sufficient to characterize which stops spirantize, because segments can be deleted and epenthesized. Rather, the correct results are generated when the rules have the order shown in (7). This order results in complex surface manifestations, with Spirantization being bled by morphological infixation and gemination, being fed by epenthesis, and standing in both bleeding and counterbleeding order with Schwa Deletion.

⁷ Glottal stop also does not meet the [–son] condition, if we follow Halle (1995) in assuming that all elements without Oral Place are necessarily glides. Chomsky and Halle (1968) likewise propose that glottal stop is a glide.

⁸ These observations can be adapted to OT in fairly obvious ways. For instance, if we analyze spirantization as a positive requirement that obstruents following vowels should contain a Guttural node, then gutturals, emphatics, and laryngeals meet this requirement without having to be modified. Of course, this does not explain why single stops meet this requirement by adding [spread glottis] and geminates meet it with [constricted glottis]. One obvious way to try to deal with this would be to formulate a constraint against geminate aspirates. This mechanism must then deal with the problem of geminate spirants arising through syncope, as in [təva:rexxá:] ‘bless 3FS IMPF 2MS’ Gen. 27:4, [to:xxá:] ‘inside-of 2MS’ Ezek. 28:16, and [bəhiθhalexxá:] ‘when walk Hitpa’el 2MS’ Prov. 6:22 (McCarthy 1986, Malone 1989).

Thus, Spirantization is not at all surface apparent, but there is a place during the derivation where it can apply and have all of the correct effects. Furthermore, much of the rule ordering is intrinsic. Since epenthesis is a by-product of syllabification and the environment for Spirantization is postnuclear, these two processes are intrinsically ordered, with syllabification (and therefore epenthesis) preceding and creating nuclei for Spirantization. Therefore, it is unnecessary for the learner to extrinsically order syllabification (and therefore epenthesis) and Spirantization. The Hitpaʕel “metathesis” is a morphological rule and thus precedes all phonological rules, including Spirantization. The only relevant extrinsic ordering is between Spirantization and Schwa Deletion. However, notice that once a learner has discovered that Spirantization is postnuclear, the “opaque” application of Spirantization in forms such as (2b) is exactly the evidence the learner requires to determine that Spirantization must precede Schwa Deletion. Notice, also, that I do not say that languages lacking postnuclear spirantization order Spirantization before syllabification, shadowing its effects. An account taking that position would be incapable of deriving any meaningful principles of intrinsic ordering, such as the obvious one suggested here. Thus, we are left with two questions for further research: (a) why Spirantization occurs in a postnuclear environment, and (b) why Schwa Deletion follows Spirantization.

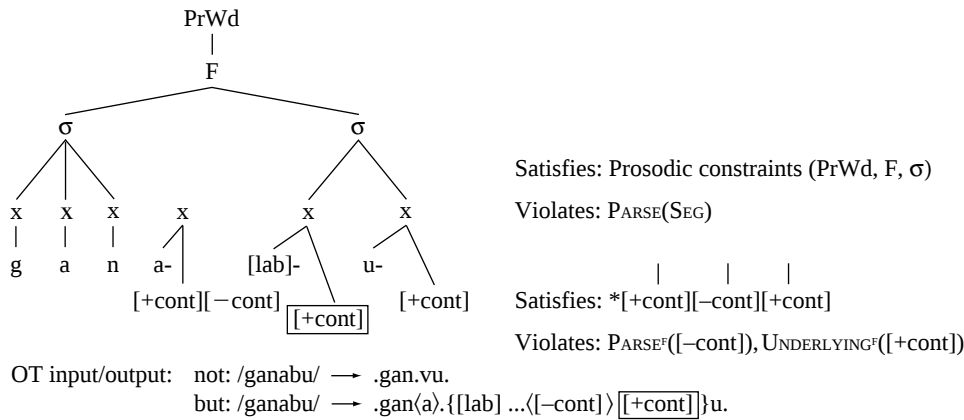
We will now turn to consideration of possible nonderivational accounts of Hebrew spirantization.

3 Containment Accounts

The two main versions of OT, presented in Prince and Smolensky 1993 and McCarthy and Prince 1995, differ in their approach to insertions and deletions (violations of faithfulness). In Prince and Smolensky 1993 a principle of containment is assumed that prevents structure from being literally removed from output candidates. Thus, no structure is deleted in the phonology per se; however, some of it is rendered uninterpretable in the phonetic implementation component. The idea is that in order to be pronounced, a node or segment must be linked into higher prosodic structure (parsed). Any unparsed material is left unpronounced and then does not appear phonetically. In Prince and Smolensky 1993 underparsing is denoted by an absence of relevant structure. Parsing is equated with Itô’s (1986) Principle of Prosodic Licensing, but there is an important difference. Itô’s principle is one universal condition on representations, whereas the OT parsing constraints are a large collection of particular path requirements between pairs of nodes, such as syllable nodes and root nodes.

Smolensky (1995) has offered an OT analysis of Hebrew spirantization; his explanatory diagram is reproduced in figure 1. The diagram shows that [+cont] has been added by Gen (as indicated by the surrounding box). The underlying vowel /a/ is not parsed into any syllable and therefore is unparsed and unpronounced. However, the features of the unparsed vowel are still in the diagram; so, for instance, the [+cont] specification of the /a/ can count for the purposes of the [cont] constraint. Smolensky’s (1995:3) general principle is given in (24).

- (24) Unpronounced material is visible to constraints: input material which is not pronounced is still present in the output (of Gen) and can therefore affect pronounced material through constraints (exactly as in syntax).

**Figure 1**

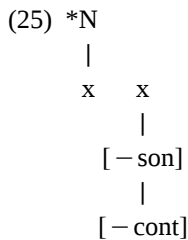
Smolensky's (1995) OT analysis of Hebrew spirantization

Now, what is especially significant here is that the [cont] constraint is formulated with upward lines, meaning that the constraint is operative on three adjacent *parsed* instances of [cont]. Therefore, the unparsed [-cont], though present in the output, does *not* affect the surrounding pronounced material, because the formulation of the [cont] constraint specifically ignores any unparsed material. But now we must examine what sort of adjacency and temporal relations are implied by the diagram and the constraint. The addition of the [+cont] node out of line with the other [cont] nodes might be an indication of agnosticism with respect to the relative order between the inserted [+cont] and the unparsed [-cont]. However, it has been standardly assumed that each feature defines a tier and that the elements of each tier are totally ordered, and Smolensky offers no reasons to doubt these assumptions (which furthermore make the tiers into highly constrained mathematical objects; allowing partial orderings on tiers would increase the power substantially, resulting in a much less constrained theory). At least it is clear that the inserted [+cont] must lie between the underlying [+cont]'s. Then how are we to interpret the [cont] constraint? It says that the sequence [+cont][-cont][+cont] when all are parsed to higher structure is a violation. By virtue of not parsing [-cont], the analysis in figure 1 does not violate this. But it isn't necessary to add a [+cont] specification to achieve this result; underparsing [-cont] is sufficient. Thus, there must be further high-ranked constraints that force each segment to be specified for [cont].

Unfortunately, there are some serious errors in this treatment. As noted earlier, the environment for Spirantization is postnuclear, not intervocalic, and the nuclear information is crucial to the operation of Spirantization. It is clearly incorrect to state spirantization solely in terms of [cont], because /s/ does not trigger spirantization, and it is unnecessary to include any right-hand context, as can be seen by spirantization at the ends of words such as [ka:θáy] 'write 3MS PERF'.

3.1 A Prosodic Spirantization Constraint

Given Smolensky's account as a model, it is relatively simple to turn the rule in (18) into a constraint, as in (25).



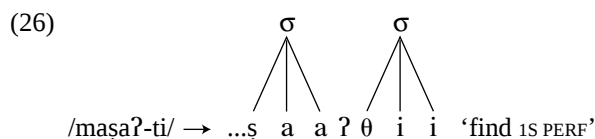
Of course, if the rule in (18) is ad hoc, and indicative of the “morass of rewrite rules” (Smolensky 1995), then the simple-minded translation in (25) can be no better. As a phonological universal the constraint has no more or less plausibility than the rule does. Constraints such as (25) offer no better explanation of the phenomena, or of the nature or catalogue of the kinds of constraints allowed by Universal Grammar. If we can simply build up any phonological representation and label it as “undesirable,” then the theory of OT constraints is just as arbitrary as any rule system. Any theory that allows arbitrary constraint formulations is not a significant improvement over rule theories.

Formulating spirantization as in (25) results in two problems: a parsing paradox and inconsistent interpretations of unparsed elements. As demonstrated above, for the operation of spirantization across /y w/ to be predicted correctly, the spirantizing stop must be postnuclear (I will consider the Place alternative below), and this is dutifully embodied in (25). However, a problem now arises with the deleted (unpronounced) vowels. If spirantization is formulated as postnuclear, then any vowels causing spirantization must be parsed into the nucleus. However, in order for deleted vowels not to be realized phonetically, Prince and Smolensky (1993) require that they not be parsed. Obviously, this is a paradox: the vowel cannot be both parsed as a nucleus and unparsed. That is, there is no way in which unparsed vowels can correctly condition a prosodic version of the spirantization constraint, such as (25).

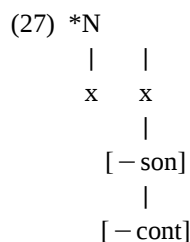
A referee suggests that instead of leaving vowels wholly unparsed, we could instead parse the vowels into a nucleus, but leave the nucleus unparsed. This would allow such vowels to condition spirantization through (25). Though this idea deviates from the theory in Prince and Smolensky 1993, it is very interesting, for it gives us the possibility of having two kinds of unparsed vowels: those completely unparsed, and those in an unparsed nucleus. Since deleted vowels show two behaviors, either conditioning spirantization or not, we could analyze the spirantizing deleted vowel as part of an unparsed nucleus: [gan<[a_{Nuc}])vu] versus [yix(a)tov]. However, the appropriate constraints on parsing vowels and nuclei would have to be formulated, and I cannot see how they could be formulated to give the desired effects. This idea also predicts that it should be possible to have at least two kinds of deleted consonants: totally unparsed, and partially parsed (in an unparsed Coda or mora, for example). Since Hebrew has very few deleted

consonants, it is difficult to test this prediction. However, no matter how deleted glottal stop is handled, it causes a problem of adjacency interpretation, to which I now turn.

Spirantization must be able to take place across a deleted glottal stop, as shown in (26).

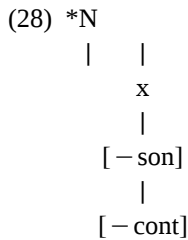


As written, (25) looks at adjacent timing slots or root nodes. Clearly, /t/ (surfacing here as [θ]) is not adjacent to the vowel on the timing or the root tier, because the glottal stop (which by hypothesis remains in the Gen output) intervenes; thus, a surface [t] here would not violate (25). Hence, there is no reason to spirantize the /t/. This is the wrong result, and the constraint must somehow be able to ignore the glottal stop; that is, the unparsed glottal stop must be invisible to the operation of (25). Following Smolensky, one way to encode this into (25) is to add an upward unanchored line to the obstruent, as in (27).



However, (27) by itself does not resolve the problem, because it still requires adjacency at the level of the timing or root tier. Obviously, we must remove this adjacency requirement. However, spirantization is a strictly local process that is blocked by any kind of intervening coda consonant, including the rare cases of coda laryngeals, (5d). Therefore, we cannot let constraint (27) apply to both a following coda and a further following onset. There is an adjacency interpretation that yields the right results for this case: adjacency of syllable affiliation lines. That is, if the lines extending upward from the root nodes are interpreted as being any valid links to prosodic structure (nucleus, coda, or onset), and if they must be interpreted as adjacent “links,”⁹ but the root nodes are crucially not interpreted as adjacent, then the correct results for spirantization across unparsed glottal stop will emerge, provided that the unparsed glottal stop is truly unparsed, and not part of an unparsed coda or mora. This must, of course, be correctly encoded in the constraint, and that entails eliminating one of the timing or root nodes in (27). Clearly, it must be the first one, because the “target” consonant must be specified as parsed. Therefore, the prosodic OT constraint must be as shown in (28).

⁹ This is reminiscent of the total ordering of featural association lines employed by Goldsmith (1976) in one formulation of the Well-Formedness Condition.

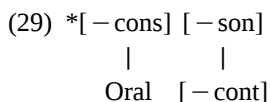


In this formulation only the syllabic affiliations are adjacent; that is, the constraint requires that the affiliations between the segments and syllable structure be adjacent. Notice that (28) cannot be understood to apply to elements in adjacent syllables with no parsed element intervening, for spirantization can take place inside a single syllable. Moreover, the interpretation will become even more complicated if unparsed nuclei condition spirantization, as suggested above. Since a following onset is not part of any nucleus, and the unparsed nucleus is not part of any syllable, there will be no shared level of higher prosodic structure upon which to base adjacency. Thus, the affiliation between the nucleus and some unspecified timing element is adjacent to the affiliation between some obstruent timing element and its dominating syllabic position (onset or coda, or σ or μ). It is unclear, however, whether syllabic affiliations (or feature associations) are elements that are ordered phonologically in the same way that timing elements or individual features are ordered on a tier. This depends crucially on the exact definition of feature associations (perhaps as points of synchronization in time) and syllable affiliations (whose fundamental formal nature is still unclear), and I will not pursue this complicated foundational issue here.

In summary, “syllable-parsing adjacency” is simply an ad hoc mechanism for allowing unparsed elements to be invisible rather than visible, in direct violation of Smolensky’s general claim that “[u]npronounced material is visible to constraints.” Furthermore, the use of such “dangling” upward lines is a powerful extension to the notational system of phonology, especially if an unparsed nucleus must condition (28).

3.2 A Segmental Spirantization Constraint

Instead of reformulating (18) as an OT constraint, we could create an OT version of (21), capturing spirantization across /y w/ by means of their characterization as glides with Oral Place nodes, (29). I will ignore the shortcomings of this approach with regard to word-final glides, explained above.



Of course, something must prevent underparsing the Oral Place node to satisfy this constraint. I will assume that such a constraint— $\text{PARSE}(\text{ORAL PLACE})$ or some equivalent—can be formulated and ranked appropriately, though I will not pursue its actual formulation or ranking here.

Now a different problem arises. Spirantization occurs after epenthetic vowels, and epenthetic

vowels are harmonic with the preceding vowel under certain circumstances. Prince and Smolensky (1993) treat epenthetic segments as empty prosodic positions; McCarthy's (1993a:188) summary of this theory is quoted in (30).

- (30) An epenthetic vowel is an empty syllable nucleus . . . which is to be cashed in phonetically for a default vowel . . .

The assimilation of epenthetic vowels in Tiberian Hebrew (similar to the Dorsey's Law vowels in Winnebago) points to the vowels' gaining their specification from their phonological environment. This has been handled in derivational theories by inserting a partially specified element and then spreading features onto it. However, in Prince and Smolensky's (1993) account the empty nucleus—being a pure prosodic position and nothing more—is supposed to be completely inert phonologically, and then is interpreted as the “default” vowel phonetically. Indeed, when there is no harmonizing vowel, and when the epenthetic vowel is in an open syllable, it is realized as a neutral central vowel. McCarthy and Prince (1993b) are aware of the problem of epenthetic vowel harmony and even cite Tiberian Hebrew in this respect. The problem goes deeper than that, however, for the epenthetic vowels trigger spirantization even when they have the “default” pronunciation. But if the unassimilated epenthetic vowels (or, a fortiori, all epenthetic vowels) are featureless prosodic positions, then it is clear that they will not have Oral Place nodes, and thus will not properly condition spirantization through (29).

Another problem arises in trying to determine adjacency conditions and thereby the visibility of unparsed elements. Recall that spirantization applies across an unparsed (deleted) glottal stop and that it is also induced by an unparsed vowel. The relevant cases are repeated in (31).

- (31) a.
- σ

 ...ʃ a a
 V C

σ

 ʔ i i
 C

'find 1S PERF' (= (4e))
- b.
- σ

 k a a θ
 V C V C

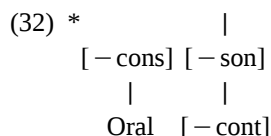
σ

 a v u u

'write 3P PERF' (= (4b))

In (31) the elements that must be examined for the constraint to do the requisite work are indicated. In (31a) the unparsed glottal stop must be ignored in evaluating the constraint. In (31b), however, the unparsed vowel must not be ignored. One can conclude from this that the constraint does not care about the parsing of the vowel, but does care about the parsing of the consonant. One way to describe this situation is that unparsed potential targets are invisible, but unparsed potential triggers are visible (see below for a proposal by McCarthy (1995) to add parameters on the evaluations of constraints that achieve an effect somewhat like this). It is also important to note

that constraint (29) cannot specify which syllable the consonant is parsed into, for spirantization occurs sometimes within the same syllable [ka:θáv], sometimes between adjacent syllables [ka:θáv], and sometimes between a syllable and an unparsed element [ka:θ(a)vú]. The constraint must be modified to include these parsing requirements, using Smolensky's upward unanchored line, (32).



Therefore, again we need to declare for each element in a constraint whether it must be parsed to be visible. This obviously gives us essentially the power to simply declare for each element of a constraint whether it ignores unparsed elements or not. Thus, Smolensky's dictum that "[u]nparsed material is visible to constraints" is simply not true in the general case. Constraints must in fact encode whether or not they consider the parsing of each individual element relevant, making invisibility a diacritic notion. This means that the theory in Prince and Smolensky 1993 lacks any general theory of adjacency or visibility: each relation must be established for each element of a constraint separately. In contrast, derivational theories have an obvious and intuitive notion of adjacency and visibility: if something is there, then it is visible; if an element immediately precedes another element, then the two are adjacent.

More evidence against (32) comes from examining what adjacency relations must hold there. As written, (32) requires root node adjacency, for the features [cons] and [son] are contained in the root node (see McCarthy 1988). However, (31a) clearly shows that root node adjacency is too strong a condition, for spirantization takes place across a deleted glottal stop. But [-cons] is required because nonvocoids do not cause spirantization. Furthermore, adjacency of Oral Place with the obstruent is too weak a condition, for syllabified glottal stop does block spirantization. Therefore, there is no adjacency interpretation of (32) that will do the requisite work.

Thus, the segmental spirantization constraint (32) fails, because it does not account for spirantization following epenthetic vowels, and it is unable to support any legitimate interpretation for the adjacency relations between the elements of the constraint. In contrast, the prosodic spirantization constraint (25) failed because it cannot correctly condition spirantization after unparsed vowels. We can conclude that neither the prosodic spirantization constraint (25) nor the segmental spirantization constraint (32) can handle all of the environments in which spirantization occurs.

3.3 Constraint Combinations

As just outlined, the two spirantization constraints (25) and (32) fail on nearly complementary sets of data. The prosodic formulation works for epenthetic vowels, and with upward unanchored lines it works for spirantization across unparsed consonants, but it cannot handle deleted vowels. On the other hand, the segmental formulation (when interpreted to require root node adjacency) works with deleted vowels, but it does not work either for spirantization across unparsed glottal

stop or with epenthetic vowels. One might conclude, then, that both formulations of spirantization need to be active in the grammar.

However, this is a bad analysis conceptually. Spirantization is a unified process and has remained so in Hebrew grammar for centuries. The changes it has undergone (limiting the set of stops it affects to /p b k/ in Modern Hebrew, for example) apply uniformly in all the different environments of spirantization. Splitting spirantization into two or more processes (with a great deal of overlap in their coverage; e.g., all vowels that are present at both UR and SR) explicitly abandons any unified account of spirantization. It is then simply an accident that the two putative constraints must have the same ranking and that thousands of years have not caused their rankings to diverge. Furthermore, this solution affords no insight into why (25) and (32) have so much in common. The idea of simply including both constraints in the grammar misses generalizations on both the analytic and explanatory levels: parsed underlying vowels trigger violations of both constraints, an analytical duplication of effort; and the theory has no explanation for the near formal identity of the two constraints.

But there is yet one more empirical problem that cannot be overcome by including both constraints (25) and (32) in the grammar: the imperfective verb cases, such as (33).

(33) /ya-katob/ → [yixtó:v] *[yixθó:v] ‘write 3MS IMPF’

Even the conjunction of the two constraints cannot account for the lack of spirantization following unparsed vowels in these forms. If /a/ in [ga:n(a)vú:] is sufficient to cause spirantization of /b/, then underlying /a/ in [yix(a)tó:v] should cause spirantization of /t/, but this does not occur. As mentioned above, one line of attack on this problem would be to distinguish between unparsed vowels, and vowels in unparsed nuclei, but this will require some work to formulate parsing constraints on vowels and nuclei to achieve the necessary parsings.

To complicate matters further, some infinitive construct forms (related to the imperfective) do show spirantization (e.g., /b#katob/ → [bixθó:v] ‘when writing’) whereas others do not (e.g., /l#katob/ → [lixtó:v] ‘to write’), the forms motivating the cyclic analysis in Prince 1975. These forms strongly indicate that no simple account in terms of parsed and unparsed vowels and consonants will suffice. Of course, we could recapitulate the rule-based analysis by dividing the phonology into several subcalculations, but this would return us to a derivational theory of phonology, exactly the question at issue. Since no nonderivational analysis is possible in the theory developed in Prince and Smolensky 1993, let us turn to accounts invoking one of the several modifications that have subsequently been proposed in OT: input-output and output-output correspondence constraints.

4 Correspondence Accounts

As we have seen, the version of OT as developed in Prince and Smolensky 1993 cannot account for the facts of Tiberian Hebrew spirantization. Because unpronounced elements are not removed in the phonology, no coherent theory of adjacency relations can be supplied, and no unified account of spirantization can be given. As McCarthy and Prince (1993b) indicate, Prince and Smolensky’s (1993) claim that epenthetic elements are empty prosodic positions is also problem-

atic because epenthetic vowels can be harmonic with neighboring vowels, as in Winnebago and Tiberian Hebrew. If this is achieved in the phonetic interpretation of the empty prosodic positions, then the phonetic implementation component must be enriched to include processes of vowel harmony, and such a move duplicates the powers of the phonology in phonetic implementation. To address these problems with OT as developed in Prince and Smolensky 1993, McCarthy and Prince (1995) have proposed that the containment principle be abandoned and that the input-output relation be evaluated directly with correspondence constraints of faithfulness, which, in perfect form, would ensure that every node and structural relation encoded in the input is preserved in the output, and vice versa.¹⁰

McCarthy (1995) and Benua (1995) offer complementary accounts of Tiberian Hebrew spirantization employing correspondence theory. McCarthy proposes to enrich the theory of constraints by parameterizing certain aspects of constraint evaluation. Benua analyzes the paradigmatic aspects of Tiberian Hebrew spirantization, arguing for correspondence relations of faithfulness between surface forms in the same paradigm (output-output correspondence). McCarthy's (1995:7) formulation of the Tiberian Hebrew spirantization constraint is given in (34).

(34) *No-V-STOP, Tiberian Hebrew version (with opacity . . .)*

<u>*</u>	<u>Condition</u>	<u>Level</u>
α	V	Indifferent
β	[– son, – cont]	Surface
Linear Order	$\alpha > \beta$	Indifferent
<u>Adjacency</u>	<u>Strict</u>	<u>Indifferent</u>

Each Level parameter has three possible settings: Surface, Underlying, or Indifferent. McCarthy (1995:7) explains that “[i]n correspondence terms, the meaning of this constraint is this: the constraint is violated if a surface stop β or its *underlying correspondent* is immediately preceded by a vowel” (emphasis in original). It is clear from the explanation that the parameter value Indifferent is the disjunction of the parameter values Underlying and Surface. Thus, including Indifferent as an evaluation parameter setting is equivalent to the disjunction of a purely surface constraint and a constraint partially defined on the underlying level. This theory is, however, less profligate than a theory that would allow the disjunction of any two arbitrary constraints. The parameterized constraint schema employed in (34) introduces some quirks of interpretation. For example, as McCarthy points out, if all constraint parameters are set to Underlying or Indifferent, then the constraint will be useless, for it will be impossible for Gen to produce any structure that lowers the violation count.

¹⁰ The use of correspondence constraints raises interesting questions for Gen. One possibility is that each candidate is generated with a correspondence function to the input. This would exponentially increase the size of the candidate set. The other possibility is that Gen produces only surface phonetic strings, which do not include derivational information. In this case Eval would have to assess each candidate under the various possible correspondence possibilities. The difference between these two positions is subtle but real, for the second could allow a candidate to emerge as optimal through different correspondence relations for different constraints.

Unfortunately, constraint (34) is empirically inadequate, for the claim that underlying vowel-stop sequences always surface with spirantization is false. First, (34) cannot handle imperfective verb forms, such as /ya-katob/ → [yixtó:v] ‘write 3MS IMPF’. As discussed above, the crucial problem is to be able to distinguish deleted vowels that do trigger spirantization [ga:n_vú:] from those that do not [yix_tó:v]. McCarthy does not discuss these cases, nor does he discuss the infinitive construct cases, such as /b#katob/ → [bixθó:v], which motivated the cyclic analysis in Prince 1975.

Second, stops that surface out of postvocalic position through the Hitpaʕel metathesis (5e)¹¹ do not spirantize: for example, [hiθqattəl] ‘kill’ (without metathesis) versus [hiʕtakker] ‘hire’ (with metathesis). But if the various realizations of the Hitpaʕel are due to morphophonological constraints against *[+strident] sequences in the Hitpaʕel (the obvious OT analysis), then (34) will incorrectly predict that the /t/ will spirantize whether or not it metathesizes. One might think that setting the linear order parameter in (34) to Surface would solve the problem. But this will then prevent spirantization following a deleted underlying vowel: because the deleted vowel has no surface correspondent, the adjacency condition cannot be met; therefore, the constraint will not be violated, and the stop will not spirantize.

As discussed above, the /t/ of the Hitpaʕel is an infix in other Semitic languages. Thus, it might be possible to circumvent the problem in this case by claiming that the /t/ is underlyingly unspecified for its exact position and hence is not underlyingly adjacent to the /i/. Adopting such an analysis would raise two problems. The first is an analytic duplication of effort: there would now be two ways to analyze metathesis, one in which items were unspecified for underlying position, and the other the standard correspondence theory account employing violations of linearity. The second problem is that this analysis would undermine the functional determination of prefix versus infix argued for in Prince and Smolensky 1993. Prince and Smolensky directly relate the placement of the Tagalog prefix/infix *-um-* to the fact that it is vowel-initial. Being vowel-initial, it shows up as an infix with consonant-initial stems because that is optimal in terms of syllable structure. Thus, they argue that it is the VC shape that drives this behavior and that such behavior would not be observed with a CV prefix. Thus, the partially infixing behavior is predictable from the underlying shape of the prefix. But the phonological shape of /t/ is insufficient to trigger metathesis in Hebrew. Other /t/ morphemes do not metathesize with following coronal sibilants, as shown in (35).

- (35) /#t-šwb-at/ [liθšu:vaθ] ‘to (an) answer CONST’ *[lištu:vaθ] 2 Sam. 11:1
 /šwb/ ‘return, repeat’

A more complicated example of an underlying vowel-stop sequence surfacing without spirantization involves the so-called lamed-he weak verbs (historically root-final /y/ or /w/), such

¹¹ It is somewhat odd that McCarthy does not consider this case, since he remarks (1995:10) that some alternative formulations of constraint parameter settings “can be teased apart empirically only in languages where the linear order and adjacency relations vary independently—e.g. in metathesis.”

as [ga:lá:] ‘reveal 3MS PERF’. As explained in Benua 1995, the final glide had been lost historically, so that in Tiberian Hebrew these verb stems are vowel-final (in standard references, such as Gesenius 1910, the roots are cited with a final /h/, hence the terminology).¹² As further explained in Benua 1995, these verbs have apocopated jussive forms of the imperfective, losing the stem-final vowel: for example, /ya-gale/ → [yíyél] ‘remove 3MS JUSS’ Job 20:28. In Benua’s analysis, the jussives are formed from the corresponding imperfectives by truncation of their stem-final vowel. Although this is described as if it is a derivation from one surface form to another (/ya-gala/ → [yíylé] → [yíyél]), it is presumably instead an evaluation of the similarity of the two surface outputs. However, which form (underlying or surface) is the input for the formation of jussives does not matter for present purposes since both /ya-gala/ and [yíylé] are vowel-final. Thus, we can test (34) by finding cases of third person masculine singular jussives (which have no suffix) followed by words beginning with /b d g p t k/. Unfortunately for (34), spirantization is not observed following truncated jussives, as shown in (36).

- (36) a. /w#ya-bane dawid/ → [wayyiven d̥a:wí:ð] ‘and build 3MS JUSS David’ 2 Sam. 5:9
 b. /w#ya-ʕale dawid/ → [wayyaʕal d̥a:wí:ð] ‘and ascend 3MS JUSS David’ 1 Chron. 13:6

The full imperfectives of these verbs, on the other hand, do allow spirantization of the initial stop of a following word, as illustrated in (37).

- (37) /ya-bane bayt/ → [yivne ʔayit] ‘build 3MS IMPF house’ Ps. 127:1

The correspondence relations for (36a) are shown in (38). (38a) and (38d) are repetitions of the underlying representation, (38b) shows the jussive output, and (38c) shows the regular imperfective output.

- (38) a. / y a - b a n e d a w i d / Input
 | | | | | | | | | | JUSS I-O correspondence
 b. [y a v e n d a : w i : ð] JUSS
 | | | | | | | | JUSS-IMPF O-O correspondence
 c. [y a v n e ð a : w i : ð] IMPF
 | | | | | | | | IMPF I-O correspondence
 d. / y a - b a n e d a w i d / Input (repeated)

¹² The lamed-he terminology is particularly unfortunate, for there are verb roots with final /h/ (e.g., /gbh/, /kmh/, /ngh/, and /tmh/). As Gesenius (1910:208) notes, “Of quite a different class are those verbs of which the third radical is a *consonantal* [h/] (distinguished by *Mappîq*). These are inflected throughout like verbs *tertiaie gutturalis*.”

Notice that the surface [d] of the word following the jussive, (38b), has an input correspondent /d/ that is adjacent to an underlying vowel /e/, which does not have a surface correspondent. Therefore, this structure violates (34). Viewing the problem paradigmatically results in a similar conclusion. The surface [d] following the jussive corresponds to a surface [ð] following the imperfective, (38c), which follows a surface and underlying vowel in that form. So the two representations possibly exerting pressure on the jussive (the underlying representation and the surface representation of the related imperfective) agree with respect to (34) that the following stop should be spirantized. But unfortunately it is not.

Nor can we appeal to some kind of phrasal explanation for the failure of spirantization with jussives. When the second root consonant is /y/, as in (36b), the shortened jussives end up being vowel-final at the surface anyway, and in such cases phrasal spirantization of a following stop can be observed, (39).

- (39) a. [wayhi: ða:wi:ð] ‘and be 3MS JUSS David’ 1 Sam. 23:26, root /hy(h)/
 b. [wayhi: feley] ‘and live 3MS JUSS Peleg’ Gen. 11:19, root /hy(h)/

In the one attested case where the second root consonant is /ʔ/, /rʔ(h)/, two kinds of behavior are observed, as shown in (40).

- (40) a. [wayyar da:wi:ð] ‘and see 3MS JUSS David’ 1 Sam. 26:5
 b. [yé:re farʔo:] ‘see 3MS JUSS Pharaoh’ Gen. 41:33

The difference in spirantization between the cases in (36) and (40a) and those in (39) and (40b) is easy to understand in surface terms. Spirantization occurs in (39) and (40b) because the preceding word ends in a vowel at the surface. In (36) and (40a) no spirantization occurs because the preceding word ends in a consonant. This is a familiar effect in derivational analyses: phrase-level phonology is calculated using the output of the word-level phonology. Because the word-level phonology determines whether the word ends in a vowel or a consonant, the phrase-level phonology is incapable of “looking back” to representations prior to the output of the word level. However, in a nonderivational analysis employing constraints such as (34) in which the underlying representations can exert direct influence on the phonetic output, we expect spirantization in all of these cases because underlyingly all of these jussives end in a vowel: /ya-bane/, /ya-ḥaye/, /ya-raʔe/.

It is necessary at this point to ask how the rule-based analysis would handle these forms. The general aspects of jussive formation are beyond the scope of this article; they include, for instance, vowel changes in the Hifʔil. For the cases at hand, it is sufficient to posit a rule of allomorphy that inserts the vowelless root in place of the verbal stem in these jussive forms. The form and behavior of the jussives will then be similar to that of segholate nouns, as shown in (41). Recall that (a) consonants can be extrasyllabic and (b) epenthetic vowels are not projected onto the grid and are therefore invisible for stress assignment. Syllabification differs slightly in the two blocks; the noncyclic block does not allow a sequence consisting of a closed syllable and an extrametrical consonant.

(41)	a. 'build'	b. 'spy'	c. 'live'
Morphology	/ya-bn/	/ya-ʃp/	/ya-ħy/
Cyclic	(yáb)n	(yáš)p	(yáh)y
Closed-Syllable <i>i</i>	(yíb)n	(yís)p	(yáh)y
Noncyclic	(yí)(be)n	(yí)(ʃe)p	(yá)(ħe)y
Spirantization, etc.	[yíven]	[yíʃef]	[yahí:] ¹³

Because in this analysis the jussive truncation is morphological, there is no final vowel at any point in the phonology for (41a–b). Therefore, it is impossible for these forms to condition Spirantization of a stop at the beginning of the following word. Form (41c), on the other hand, ends up with a final vowel at the end of the word phonology and can therefore condition Spirantization in the phrasal phonology.

The forms in (40) are also interesting because they illustrate an interaction between epenthesis and laryngeal deletion. The imperfective of 'see' is [yirʔé] Gen. 22:8. Derivations for this root and for /ya-ʔate/ → [yaθ] 'come 3MS JUSS' Isa. 41:25 are shown in (42). In order to generate both forms of /rʔ(h)/, we need to assume that for some speakers Laryngeal Deletion applied cyclically as well as noncyclically.

(42)	Morphology	/ya-rʔ/		/ya-ʔt/
	Cyclic	(yár)ʔ		(yaʔ)t
	Laryngeal Deletion	(yár)ʔ	or	(yá)r
	Closed-Syllable <i>i</i>	(yir)ʔ		(yaʔ)t
	Noncyclic	(yí)(re)ʔ		(yá)r
	Laryngeal Deletion	(yí)(re)		(ya)t
	Spirantization, etc.	[yé:re]		[yáθ]

These word-level outputs are then used in the phrasal phonology, where only [yé:re] is capable of spirantizing a following stop.

Notice also that the derivation of [yé:re] in (42) reveals another case of opacity. The /ʔ/ conditions vowel epenthesis but is then deleted later in the derivation. If Benua (1995) is right in analyzing jussives as truncated imperfectives, then we should expect [ye:re] to resemble a truncated [yirʔé]. Furthermore, since we cannot faithfully retain the /ʔ/, it is superfluous to epenthesize a vowel, and therefore only the monosyllabic output should result. But it is apparent that the final vowel in [yé:re] is epenthetic because it is unstressed. Finally, though the monosyllabic size of [yar] is correct, its vowel quality is surprising on Benua's account; instead, faithfulness to the [i] of the imperfective would be expected.

The same opaque interaction between epenthesis and Laryngeal Deletion can be observed in segholate nouns, as shown in (43).

¹³ The coalescence of /e/ and /y/ to /i:/ yields a full vowel, which is projected onto the grid. The surface stress pattern results from Vowel Reduction (10c), showing that coalescence must precede Vowel Reduction.

- (43) a. [péle] ‘wonder’ Exod. 15:11
 b. [kéle] ‘imprisonment’ 1 Kings 22:27
 c. [pəla:ʔi:m] ‘wonder PL’ Lam. 1:9
 d. [kəla:ʔi:m] ‘imprisonment PL’ Isa. 42:22
 e. [pilʔexá:] ‘wonder 2MS’ Ps. 77:12, 88:13
 f. [biʔðé:xilʔó:] ‘clothes CONST imprisonment 3MS’ 2 Kings 25:29

The forms (43a–b) show an epenthesis vowel, even though the underlying /ʔ/ conditioning the epenthesis is not present at the surface. The forms (43c–d) show the presence of /ʔ/ in the plural, and the forms (43e–f) show that the /ʔ/ cannot be analyzed as being epenthesis to break up hiatus.

A different problem for (34) also involves the lamed-he class of verbs. The perfective third feminine singular forms of these verbs are augmented with an epenthetic /t/, which spirantizes, as in (44).

- (44) /gala-a/ → [ga:lθá:] ‘ascend 3FS IMPF’ Lam. 1:3

In an analysis based on derivational rules, this is handled by a minor morphological rule of stem augmentation, and consequently the spirantization is expected because the morphological rules precede the phonological ones. However, there is no derivational distinction in OT between the morphology and the phonology, and morphophonological epenthesis should be evaluated on a par with all other processes, for “the consequences of all of these processes are realized simultaneously rather than serially” (McCarthy 1995:3). The problem then is that since the [θ] has no input correspondent, the only adjacency relationships it can have must be at the surface; but at the surface there is no adjacent preceding vowel, as shown by the input-output correspondence diagram in (45).

- | | | | | | | |
|-----------------|---|----|---|---|---|----|
| (45) Underlying | g | a | l | a | - | a |
| | | | | | | |
| Surface | g | a: | l | | θ | a: |

Given the various problems raised by the lamed-he class of verbs, we might like to try to mimic the historical developments by maintaining an underlying stem-final glide (historical /y/ for (44); Gesenius 1910:207).¹⁴ However, this still results in two rather unpalatable scenarios for the input-output correspondence relation in such forms, as shown in (46).

- | | | | | | | | | | | | | | | | | |
|-----------------|----|---|----|---|---|---|----|---|----|---|----|---|---|---|---|----|
| (46) Underlying | a. | g | a | l | a | y | - | a | b. | g | a | l | a | y | - | a |
| | | | | | | | | | | | | | | | | |
| Surface | | g | a: | l | | θ | a: | | | g | a: | l | | θ | | a: |

The situation diagrammed in (46a) is inconsistent with (34) because the [θ] still does not have an input correspondent. Only an adjacent vowel at the surface can cause it to spirantize, but the

¹⁴ The existence of verbs with actual /h/ as the final radical precludes following the Hebrew orthography by using /h/ in the underlying representations here.

potentially preceding /a/ does not surface. Hence, [θ] should not be spirantized whereas in fact it is. The situation in (46b) is only marginally better. Spirantization is properly conditioned, but only at the cost of identifying /y/ as the input correspondent for [θ]. This is a rather drastic change in the identity of the segment; it is difficult to see how feature faithfulness constraints could be ranked appropriately to make this change optimal. Accounting for spirantization nonderivationally using (34) precludes analyzing (44) in terms of the epenthesis of an unmarked consonant, /t/, which is then realized by means of normal processes.

Thus, McCarthy's (1995) account does not adequately handle Tiberian Hebrew spirantization. By allowing surface spirantization to be conditioned by underlyingly adjacent vowels, it incorrectly overgenerates spirantization in imperfectives, in metathesized Hitpa'el forms, and following jussives, and it undergenerates spirantization in cases of epenthesis.

So far I have touched only tangentially on Benua's (1995) analysis and on the potential utility of constraints mandating paradigm uniformity (see also Flemming and Kenstowicz 1995, Kenstowicz 1995). It is difficult to discuss Benua's examples in detail because she assumes that the imperfective stems are underlyingly /CCVC/, an assumption that is inconsistent with the findings of McCarthy and Prince (1990), McCarthy (1993b), and Dobrin (1993), discussed above. It is also difficult to assess Benua's account of identity effects in imperative truncation because she does not discuss the relatively large number of pe-nun verbs that retain /n/ in the imperative but lose it in the imperfective (e.g., /nqm:/[nəqó:m] 'avenge 2MS IMPER' Num. 31:2, [tiqqó:m] 'avenge 2MS IMPF' Lev. 19:18). Other roots showing this behavior include /ntš/, /ntʃ/, /nθ/, /nʃr/, /ndr/, /nqb/, and /ntʃ/.

It is possible, however, to make some general comments about the application of paradigm uniformity to Tiberian Hebrew spirantization. The first work to apply paradigm uniformity to spirantization within generative phonology was Malone 1969. Recall the verbal paradigm for /ktb/ in (6), repeated in (47).

(47)	<i>Perfective</i>		<i>Imperfective</i>		<i>Piʕel perfective</i>	
1S	ka:θáv-ti:	CVCVC	ʔe-xtó:v	CCVC	kittáv-ti	CVCCVC
2MS	ka:θáv-ta:	"	ti-xtó:v	"	kittáv-ta:	"
2FS	ka:θáv-t	"	ti-xtəv-í:	"	kittáv-t	"
3MS	ka:θáv	"	yi-xtó:v	"	kittév	"
3FS	kaθv-á:	CVCC	ti-xtó:v	"	kittəv-á:	"
1P	ka:θáv-nu:	CVCVC	ni-xtó:v	"	kittáv-nu:	"
2MP	kəθav-tém	"	ti-xtəv-ú:	"	kittav-tém	"
2FP	kəθav-tén	"	ti-xtó:v-na:	"	kittav-tén	"
3MP	ka:θv-ú:	CVCC	yi-xtəv-ú:	"	kittəv-ú:	"
3FP	ka:θv-ú:	"	ti-xtó:v-na:	"	kittəv-ú:	"

Throughout the entire paradigm /b/ surfaces as [v], even though not all forms have a surface vowel preceding the [v] (e.g., [ka:θvú:]). Thus, we could attribute the [v] in this form to the pressure exerted by the rest of the paradigm. But then what of the fact that /t/ surfaces as [θ] sometimes and [t] other times? We could say that paradigm pressure is limited to each individual

binyan and aspect (e.g., Qal imperfective). But there is initially a more attractive possibility. The facts that the medial /t/ is geminated in the Piʕel and Hitpaʕel and that these geminates never spirantize might provide a counterbalancing force against the pressure from the surface-true spirantization [θ] in the perfective. Therefore, in the Qal imperfective, since the paradigm pressure is equivocal, surface evaluation of spirantization in the individual form wins out, and /t/ does not spirantize. This idea can be tested, because numerous verbs do not appear to have had any Piʕel or Hitpaʕel forms. Eight roots listed in Halkin 1970 do not have Piʕel or Hitpaʕel forms, have one of /b d g p t k/ as the second root consonant, and do not lose the initial consonant of the root: /ḥdl/,¹⁵ /nbt/, /nbʕ/, /pgʕ/, /škb/, /špt/, /šth/, /tbʕ/. However, none of these cases have surface postconsonantal spirantization of the second root consonant in the Qal imperfective, as shown in (48).

(48) /ya-ḥadal/ → [yeḥdál] ‘cease 3MS IMPF’ *[yeḥðal]

This evidence rules out the initially attractive explanation of [yixtó:v] in terms of compensating pressure from [kité:v]. Therefore, we will have to restrict paradigm pressure to smaller paradigms, consisting of one binyan and aspect. Then we have a model where surface vowel-stop sequences are prohibited, and paradigm pressure causes some postconsonantal stops to spirantize.

However, by examining segholate nouns such as /malk/ ‘ruler’, (49), we can see that even within such small paradigms the pressure is not that great. The root /mlk/ has different stems in the singular (/malk/) and plural (/malak/).

(49) /malk/ [mélex] ‘king’ Gen. 49:20
 [malká:] ‘queen’ Esther 1:9
 [malkí:] ‘king 1S’ 2 Sam. 19:44
 /malak/ [məla:xí:m] ‘king PL ABS’ Gen. 14:9
 [ma:lxé:] ‘king PL CONST’ Gen. 17:16

The spirant [x] in [mélex] does not cause the first person pronominal form to be *[malxí:]. But what is the difference between /k/ in (49) and /b/ in (47)? The answer (as McCarthy (1995) indicates) is that the /b/ in (47) is preceded by an underlying vowel whereas the vowel triggering spirantization in [mélex] is epenthetic. Thus, we cannot rely solely on the surface representations of paradigms; we must also know whether the vowels (at least) are epenthetic or not. Therefore, the generalization now stands that Hebrew stops spirantize when they are next to a surface vowel, and also when they were next to a vowel underlyingly and some element of the paradigm shows surface-true spirantization by retaining that vowel. Then, because no element in the Qal imperfective paradigm retains the first stem vowel at the surface, the second stem consonant is not pressured to be a spirant and therefore does not spirantize. This generalization is true as far as it goes, but it is really nothing more than a description of environments where spirantization occurs. Without a concrete theory of paradigm structure and pressure within paradigms, it is impossible to tell what predictions such a theory makes.

¹⁵ Halkin (1970:82–83) incorrectly omits dagesh lene throughout the paradigm.

There is one set of data in Tiberian Hebrew, however, that indicates that no correspondence account of spirantization will suffice. Consider the paradigm for infinitive constructs, given in (50a). Because the infinitive constructs are related to the imperative and imperfective, these forms are shown in (50b). As remarked above, the crucial difference is between [lixtov] and [bixθov].

- (50) a. /θ-tapoś/ [təfo:ś] ‘recapture INF’ Ezek. 14:5
 /θ-katob/ [kəθo:v] ‘write INF’ (not attested without proclitic)
 /l#katob/ [lixtov] ‘write INF CONST’ Josh. 18:8
 /b#katob/ [bixθov] ‘write INF CONST’ Ps. 87:6
 b. /ya-katob/ [yixto:v] ‘write 3MS IMPF’ Isa. 44:5
 /θ-katob/ [kəθo:v] ‘write 2MS IMPER’ Exod. 17:14
 /w#katob/ [uxθo:v] ‘and write 2MS IMPER’ Ezek. 37:16

The problem for correspondence theory is to explain why the infinitive construct forms behave differently with /l#/ and /b#/. The underlying pattern and paradigmatic relationships for [lixtov] and [bixθo:v] are identical, so no account in terms of input-output and output-output faithfulness constraints can explain the difference in spirantization. This difference in behavior can be explained in derivational terms by marking /l#/ as [+cyclic] and /b#/ as [−cyclic], an insight originally due to Prince (1975). Being cyclic, /l#/ behaves analogously to the imperfective prefixes.

Benua (1995) also discusses the nonspirantization of the second person feminine singular ending [t] in such examples as (51) (see also Malone 1969).

- (51) /šamaʕ-t/ → [šamaʕat] ‘hear 2FS PERF’ 1 Kings 1:11, Ruth 2:8

Benua argues that spirantization does not occur in such forms because of paradigm pressure exerted by other Qal perfective forms with /t/-initial suffixes (/ti/, /ta/, /tem/, /ten/) and suffixed forms showing the full historical second person feminine singular ending /-ti-/. Malone (1969: 546) specifically restricts the paradigm pressure to the subparadigm of second person forms (of both genders and numbers; i.e., second person masculine and feminine, singular and plural) for each specific tense and binyan combination. Restricting the paradigm uniformity to the second person forms relieves the pressure in the paradigm for /krt/ on [ka:ráθ] ‘cut off/down 3MS PERF’ Gen. 15:18, which shows no tendency to retain surface [t].

There is no equivalent paradigm pressure resulting in nonspirantization in segholate nouns, as shown by (52).

- (52) /zaʕp/ → [zaʕaf] ‘rage’ 2 Chron. 16:10
 /zaʕp-o/ → [zaʕpó:] ‘rage 3MS’ Jon. 1:15

Even though [zaʕpo:] has a nonspirant [p], spirantization following the epenthetic [a] in [zaʕaf] is not inhibited. Thus, these two cases represent a minimal pair in the operation of paradigm uniformity.

I believe that Benua’s insight that the second person feminine singular [-t] is still related to its longer form [-ti-] is essentially correct. It can be captured in the derivational analysis in a straightforward manner. We cannot simply exclude the second person feminine singular suffix

from spirantization, because it does spirantize following lamed-he and lamed-aleph verbs, as in /šaneʔ-t/ → [šané:θ] ‘hate 2FS PERF’ Ezek. 16:37 (see also Malone 1969 for the same point). I propose that the underlying representation of the second person feminine singular suffix is still /-ti/, but that this suffix when word-final does not have a line 0 grid mark and therefore does not bear stress. Rule (11) deletes the final grid-mark-less /i/.¹⁶ As noted above, rule (11) follows spirantization. The reapplication of syllabification epenthesizes a vowel to break up some of the resulting clusters. (As Benua explains, not all clusters are broken up, only those involving a guttural.) This analysis allows for a very minimal allomorphy for the second person feminine singular ending, differing only in the presence or absence of a grid mark, and this is predictable on the basis of whether or not there are further suffixes.

It is possible to devise an observationally adequate account of Tiberian Hebrew in OT by allowing a multiplicity of constraints regarding spirantization. For instance, we could formulate a separate input-output constraint for any input form that we could not account for. Such a “grammar” would necessarily generate all of the correct forms, but it would have no explanatory value. We could also try to construct a solution that combines Prince and Smolensky’s (1993) underparsing deletion with correspondence theory’s actual deletion. But since correspondence theory cannot handle the nonspirantization in [yixtov], it would be necessary to set the α parameter in (34) to Surface. This will effectively make (34) into a strictly surface constraint, however: deleted vowels will not cause spirantization, but unparsed vowels will, [lixtov] versus [bix(a)θov]. Therefore, the innovations of McCarthy 1995 specifically designed to handle opacity would not be employed in the analysis at all. This also raises the question of whether unparsed nuclei could also be used with correspondence theory to produce a three-way distinction in deleted vowels: $\emptyset$, $\langle V \rangle$, and $\langle [V_{\text{Nuc}}] \rangle$.¹⁷ Thus, the problem boils down to distinguishing two kinds of deleted vowels. The rule-based theory generates two kinds of deleted vowels by having the deletion rule apply both cyclically and noncyclically, a derivational solution. It will be of great interest to see if constraints and rankings can be found that will generate some combination of distinctions between vowels that are deleted, unparsed, or in unparsed nuclei that will generate the Hebrew facts.

5 Summary and Conclusions

In this article I have demonstrated that no OT account¹⁸ of spirantization is adequate and unified in the way that the rule-based account—having a single rule of spirantization applied at one point in

¹⁶ As written, (11) requires the preceding syllable to be open, which will not be true here. However, (11) can be written in a much more general fashion, to delete all vowels lacking representation on the grid. If the revisions to the Elsewhere Condition proposed by Halle and Idsardi (1997) are adopted, this rule will then be disjunctively ordered with the epenthesis rule (which inserts a grid-mark-less vowel). The technical details of this proposal are too complicated to be discussed in the present article.

¹⁷ A previous version of this article also considered the possibility of unparsed epenthetic vowels. McCarthy (1995) discusses the ramifications of such vowels and concludes that they would seriously complicate the analysis of Lardil truncation.

¹⁸ While this article was in press, McCarthy (1997) proposed another mechanism (termed *Sympathy*) to handle cases of opacity in OT, discussing only cases such as (43). To handle spirantization with Sympathy crucially involves calculating

the derivation—clearly is. The interaction between spirantization and other morphophonological processes in Tiberian Hebrew is easy to characterize in a rule-based derivational analysis. In particular, I have argued that the Tiberian Hebrew grammar contains various rules and the crucial orderings outlined in (53).

- (53) a. Hitpaʕel Formation precedes Spirantization (bleeding)
 b. Medial Gemination precedes Spirantization (bleeding)
 c. Epenthesis precedes Spirantization (feeding)
 d. Word-Final Degemination precedes Spirantization (feeding)
 e. Laryngeal Deletion precedes Spirantization (feeding)
 f. Spirantization precedes Schwa Deletion (counterbleeding)
 g. Spirantization precedes 2FS epenthesis (counterfeeding)

The variety of effects displayed by rules (feeding, bleeding, etc.) is not unusual or surprising. As explained above, general principles of grammar determine many of the ordering relations. Since Hitpaʕel Formation and Medial Gemination are morphological rules, they must precede Spirantization. Since Spirantization is postnuclear, it must follow syllabification (and therefore epenthesis). The orderings not determined by general principles (Spirantization and syllable-based deletions) must be learned by the child. But there are very few orderings to consider and there will be abundant evidence for the orderings. The same phenomena cannot be successfully treated in a constraint-based nonderivational OT grammar. The various versions of OT are incapable of providing a unified account of spirantization. The conclusion is that Hebrew spirantization indeed confirms the necessity of a derivation, even in OT. No monostratal nonderivational solution is possible for the Tiberian Hebrew facts, and this strongly affirms Chomsky's (1995) point that a derivational approach is correct.

Since no adequate nonderivational OT analysis is possible for Tiberian Hebrew, we are now faced with the question of how much of a derivation is needed for OT to adequately capture the Tiberian Hebrew spirantization facts. This is an extremely difficult question to assess. Rather than focusing only on spirantization, it is probably better to try to cover a substantial portion of the morphophonology of Tiberian Hebrew in OT terms, parallel to Malone 1993. This is obviously beyond the scope of this article. However, the facts described above are not encouraging. At least four calculation levels would seem to be needed: the morphology, the cyclic word phonology, the noncyclic word phonology, and the phrasal phonology. But even within some of these levels, especially in the noncyclic word phonology, there are still opaque rule-orderings (e.g., the interaction between epenthesis and Laryngeal Deletion). The various grammars at these different levels will have to have different constraint rankings. In the rule-based analysis all languages have all of these levels, and there is very little difference between the grammars at different levels. In Tiberian Hebrew it suffices to have Spirantization turn on noncyclically. Therefore, the learning

faithfulness to a MAX_{IO} sympathetic candidate (see Idsardi 1997b). The result is similar to the accounts argued against here: the Sympathy theory predicts that UR vowels are sufficient to cause spirantization of a following stop, which is not the case, (5f).

problem for different levels is to establish where Spirantization turns on and off. Since OT explicitly rejects the idea that constraints can be absent from a grammar, allowing only that they can be relatively lowly ranked, the grammars of the various levels in Tiberian Hebrew in any OT account will differ significantly from each other. Also, because syllable structure changes between the levels, it will be necessary to eliminate syllable structure between the levels. However, geminate vowels and consonants persist between the levels, so the mora structure will have to be preserved between levels.

Thus, although it may not be impossible to develop a multilevel OT grammar that will be observationally adequate for Tiberian Hebrew (though whether this can be done or not remains to be demonstrated), any such theory must explain how much grammars of different levels can differ and how learners would acquire those grammars.

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