Tel-Aviv University
The Lester and Sally Entin Faculty of Humanities
Department of Linguistics

Phonotactic universals in Modern Hebrew: Evidence for prosodic alignment of stops

Thesis submitted for M.A. Degree at Tel-Aviv University

by:

Aviad Albert, Tel-Aviv University

Thesis Advisors:

Prof. Outi Bat-El and Dr. Evan Cohen

November, 2014

Abstract

The following thesis argues for a strong *Alignment* (McCarthy and Prince 1993) relationship between stop consonants and prosodic units. Although this is not an uncommon assumption, my proposal also considers sub segmental features as targets of this universal left alignment principle. More specifically, I claim that the closure node of stops is a member in the hierarchy of consonants that are universally required to align with the beginning of prosodic units such as syllables. This hierarchy of alignment constraints is presented within the framework of Optimality Theory (OT; Prince and Smolensky 1993), where it can single-handedly account for the optimal onset consonant in a VCV environment, in which the least marked C is predicted to be a stop, although it is also predicted to be a fricative in grammars that promote spirantization on grounds of well-formedness.

A major point of departure for this work lies in a case of variation in Modern Hebrew (MH) between stops and fricatives (see Adam 2002). I present a production experiment, which is based on this variation case, in order to observe the subtle phonotactic trends that are exhibited by MH speakers. I use the alignment proposal to explain one of the observed trends and I suggest a model in which the stop~fricative variation data is accounted for by the notion of *Underspecification* (Kiparsky 1982), in a sense that resembles proposals made in Inkelas' (1995) *Archiphonemic Underspecification*. I claim that an end-state for the MH stop~fricative variation is predictable in cases where phonotactic trends are attested. This is possible by the process of *Lexicon Optimization* (Prince and Smolensky 1993) which underlies the proposed model of underspecification.

Lastly, I argue that the reality of the proposed alignment hierarchy, which is articulatory by nature, has been often obscured by the over-blown, and somewhat vague, notion of *Sonority* (see Parker 2002 for extensive overview). I briefly sketch a program to redefine sonority as a strictly perceptual phenomenon which phonetically correlates with the cognitive sensation of pitch (based, to some extent, on Clements 2009). in light of this I suggest some speculative implications and predictions regarding the status of stridents, especially in strident-obstruent sequences (*S-Clusters*), and other *reversed sonority* clusters.

Acknowledgements

The process of writing this thesis was, thus far (and by far), my most serious attempt in academic research and writing. It could not have happened without the inspiration and guidance of my two thesis advisors, Outi Bat-El and Evan Cohen, who have been teaching me and guiding me since the very beginning of my B.A. studies.

The conviction that I am on the right path for my academic endeavors became clear as soon as I took Evan's *phonetics* class and Outi's *beginning phonology* class during my first year in university. Throughout the years and the various inspirational advanced courses that I took with Outi and Evan, I also had the honor and the pleasure to work with them as a research and teaching assistant. Their influence on my academic experience is immense. That said, since my thesis advisors did not find the magic cure for mistakes and misunderstandings, I must emphasize that any mistake or error in this thesis is mine.

I found another great source of inspiration for my interest in phonology at Tel-Aviv University, in Charles Kisseberth, who, sadly for me, retired before I started my M.A degree. Acknowledgements should also go to other members of Tel-Aviv University's Department of Linguistics, who I had the honor to work with, namely Ruth Berman and Irena Botwinik, both of whom taught me many things about language, above and beyond phonology.

This list of acknowledgements could not be complete without mentioning my student colleagues in the department, namely Hadass Zaidenberg and Avi Mizrahi, who have consistently been great friends, willing collaborators and reliable critics.

Lastly, my biggest thanks for helping me reach this point should go to my dear supportive mother, and to my beloved partner, Alma, who charged me with motivation to continue at times where I seemed to let go.

Table of Contents

1. Introduction

The focus of this thesis is on the distribution of stop consonants. I argue that various distributional facts regarding stops can be favorably explained as an alignment relation between syllables and stops, where stops are preferred in onsets ("left-aligned" to the beginning of a syllable) rather than codas ("right-aligned" to the end of a syllable). I formally base this on the notion of *Alignment* constraints (McCarthy and Prince 1993), one of the hallmarks of Optimality Theory (Prince and Smolensky 1993), and, more specifically, on the discussion regarding the coverage of **Align** constraints in syllable theory (McCarthy and Prince 1993, Itô and Mester 1999), namely *Coda Condition* cases (Itô 1986, 1989). I present empirical, theoretical and phonetic motivations for the strong tendency of stops to align with the beginning of a syllable. This is formally captured with the alignment constraint **Align-Left(Stop,σ)**, which is derived from the more general family member, **Align-Left(C,σ)**, a general alignment constraint that is assumed to cover Coda Condition cases.

I present an articulatory description that serves as phonetic support for this left-alignment preference, and elaborate on it by considering stops' sub-segmental nodes — the *closure* and the *release* — to show that there is a phonetic motivation to, in fact, left-align the closure node of stops (as evident by spirantization processes, as well as other familiar cases of lenition of medial onset stops). This is formally captured with the constraint **Align-Left ([–closure],σ)**.

Further support for my claims arises from phonotactic tendencies that are revealed here in Modern Hebrew (MH henceforth). I analyze data that were gathered in an experimental elicitation task with native speakers of the language. I observe subtle, yet systematic, trends in environments that exhibit unstable speech-sound alternations (i.e. variation).[1] The observed trends correlate with well-formedness phonotactic restrictions on obstruent sequences. The formal utilization of alignment is used here to account for one of the two trends found in the experiment — the preference for a fricative rather than a stop when immediately following a stop (e.g. [tf] is better than [tp]).

1. I use the term *alternation* to describe predictable and systematic (phonologically and/or morphologically motivated) sound change, while the term *variation* is reserved here to describe (seemingly) non-systematic and not fully predictable sound change.

To account for the MH data, I suggest a model of variation that is lexically triggered by underspecified input obstruents in the underlying representation of selected lexical entries. I base this model of underspecification on Inkelas' (1995) *Archiphonemic Underspecification*, which she originally employed to account for systematic sound alternations. This model of underspecification is based on the process of Lexicon Optimization (Prince and Smolensky 1993) whereby the most harmonic underlying representation is determined by the surface forms and the given grammar. I show that this utilization of the underspecification model provides the best account for the current variation as well as the predicted final state.

I adopt Adam's (2002) view of the MH spirantization-related variation as evidence of a grammar in change, which would, eventually, stabilize with fixed forms in the predicted end-state. I go over the complementary predictions that my proposal may contribute to the predictions that Adam (2002) began to sketch, to the extent that a more elaborate prediction for the final state in MH is borne out.

Lastly, I argue that the reality of the proposed alignment hierarchy, which is articulatory by nature, has been often obscured by the over-blown, and somewhat vague, notion of *Sonority* (see Parker 2002 for extensive overview). To complete this last argument about sonority, I briefly present a program to redefine sonority as a strictly perceptual phenomenon, which can be phonetically correlated with the cognitive sensation of pitch (based, to some extent, on Clements 2009). I discuss this sonority redefinition program and suggest, in its light, some speculative implications and predictions regarding the status of stridents, especially in strident-obstruent sequences (*S-Clusters*), and other reversed sonority clusters.

In the following section I present the background information for the experimental design (§2.1-4) followed by the results in §2.5. In §3 I suggest the ALIGN-LEFT scheme between stops and syllables to account for one of the trends in the data, limiting the distribution of stops in accordance with their gradual ability to align with prosody. I also discuss the theoretical benefits (§3.4), the alternative analyses (§3.5), the proper model of variation (§3.6) and the implications for assumed syllabification (§3.7). The notion of *Sonority* is re-addressed in §4, where I present a program to redefine sonority, and I explain the indirect, yet important, relevance that it has on the main topic of this paper — the distribution of stops.

2. Varying alternants: A case of unstable alternation

Modern Hebrew exhibits patterns of stop-fricative alternation that are historically related to the spirantization rule of Biblical Hebrew. However, MH phonology differs from Biblical Hebrew in ways that impede a straight-forward spirantization process that is entirely based on phonology (as briefly described below). This state of affairs is believed be the source of the current state of variation in MH, where some prosodic positions regularly trigger high degrees of stop~fricative variation.

While this paper is not focused on determining whether a natural process of spirantization does or does not occur in the phonology of MH speakers, it assumes that when high degrees of stop~fricative variation occur in MH, there are phonological motivations, not related to spirantization itself, that determine the direction and the extent of attested variation within what seems to be a freely varying environment.

The following subsections will go over the background of spirantization in Hebrew, and the current state of variation in MH, as an introduction to the experimental procedure, which utilizes the attested variation in MH to discover current phonotactic trends. The experiment and its results follow this introduction.

2.1. Spirantization in Biblical Hebrew

In Biblical Hebrew (BH), stops and fricatives were in complementary distribution. A process of spirantization changed phonemic stops (excluding glottals, emphatics and geminates) to their fricative allophonic counterparts in post-vocalic positions, as schematized by the rule in (1), a simplification from Barkaï (1974).[2]

(1) [–son] → [+cont] / V__

To exemplify the application of (1), consider a word-initial stop ([–son, –cont]) such as /b/ in the verb ***bara*** 'create' (3MS PERF). When following a vowel, it is expected to change into its

2. This is a simplified version of the Biblical Hebrew spirantization rule, which is not uncontroversial. For an overview of various proposals and complications see Idsardi (1998).

fricative ([+cont]) counterpart, [v], e.g. *yivra* 'create-3MS-IMPF'. The examples in (2) demonstrate such alternations in BH with four out of the six alternating pairs.

(2) Examples of stop-fricative alternations in BH[3]

a. **[t~θ]**, **[k~x]**

kaːˈ**θ**av 'write' (3MS PERF) Josh. 8:32

yi**x**ˈ**t**oːv 'write' (3MS IMPF) Isa. 44:5

b. **[g~ɣ]**, **[d~ð]**

gaː**ð**ˈluː 'be great' (3P PERF) Jer. 5:27

yi**ɣ**ˈ**d**aːluː 'be great' (3MP IMPF) Ruth 1:13

The domain of application for Biblical Hebrew spirantization is believed to be higher than the Prosodic Word, as it applies across word boundaries in configurations that suggest a domain such as the Phonological Phrase (Dresher 1994). According to this view, a stop consonant would loose its [–cont] feature when following a vowel, even across words, as long as the words belong to the same phonological phrase.[4] Example (3), from Dresher (1994), demonstrates how stop-initial words spirantize their stops when following vowel-final words within the same phonological phrase (PhP).

(3) /lamma/ /**t**aʕase/ /**k**o/ → [lamma **θ**aʕase **x**o]$_{PhP}$

why you.deal thus 'Why do you deal thus?' (Ex. 5.15)

2.2. Spirantization in Modern Hebrew

The phonology of MH brought about substantial changes in the segmental inventory of BH, and, crucially for spirantization, many changes in the obstruent inventory, which led to the loss of many phonetic and phonemic distinctions (for a detailed overview, see Bolozky 1978 and Adam 2002).

3. Adapted from McCarthy 1979.

4. The term Phonological Phrase roughly refers here to a unit above the Prosodic Word and below the full Intonation Phrase.

Only three alternating stop-fricative pairs survived in MH: /v~b/, /f~p/ and /k~x/. The fricative counterparts for [g], [t] and [d] ([ɣ], [θ] and [ð], respectively) do not exist in MH, neither as phonemes nor allophones. At the same time, the existing stop-fricative pairs are no longer in complementary distribution in MH for various reasons, as briefly detailed below.

The uvular stop [q] and pharyngeal fricative [ħ], are pronounced in MH as [k] and [x] respectively, yet these diachronically fronted consonants do not exhibit any alternation in MH (i.e. [k] and [x] that were historically pharyngeal or uvular appear in all environments without ever alternating). A similar process happened with the glide [w], which is pronounced in MH as the fricative [v], again, without ever alternating with [b]. Those different historical origins of the obstruents [k], [x] and [v], are only retained in MH orthography, as they are not phonetically distinct from the similar consonants that were not historically changed (and are expected to alternate).

Furthermore, the phonology of BH included geminates, which would block spirantization in words like [yi**pp**ol] 'will fall'. The facts about spirantization blockage in BH were among the prominent examples in a series of seminal papers that dealt with the representation of phonological length in multi-tiered frameworks (a partial list includes Leben 1980, McCarthy 1981, Hayes 1986, Schein and Steriade 1987). Although the theoretical formulations differ, a shared claim assumes that "true"/"real" geminates behave like a single entity on the segmental tier. Phonological processes that change the segmental make-up of consonants cannot affect only one half of a real geminate.

The complication in MH arises from the fact that it has no geminates, yet spirantizable consonants that were historically geminates do not alternate. Therefore, in MH, the word [yi**p**ol] 'will fall' never changes to *[yi**f**ol], although there is no geminate to naturally block spirantization in that post-vocalic position.

Lastly, MH freely adopts loanwords into its lexicon, even when they exhibit violations to the current MH spirantization norm, with no adjustments that would allow it to conform with standard spirantization requirements (e.g. word-initial fricatives, such as in the words *falafel* ([faˈlafel]), *fax* ([faks]) and *fillet* ([fiˈle]) are never adjusted to **palafel*, **pax* and **pillet*). This characteristic is carried through the lexical derivation of loanwords as denominative verbs, where a word like *fax* will get the non-alternating verbal form *fikses*, not **pikses* 'sent a fax'.

This last bit should be attributed to a process known as *transfer from the base*, in-line with Bat-El's (1994) account of MH morphology, where denominative verbs serve as evidence that novel verbs in MH are formed from other words (e.g. [faks]) by a process of Stem Modification (Steriade 1988), not from abstract root consonants (e.g. *P-K-S*). Otherwise, at least some variation should have been expected (e.g. ***f**ikses* ~ *****p**ikses*).

It is safe to conclude with a claim that many stop-fricative alternations in MH seem to be retained through lexical (prescriptive/normative) rules and by virtue of morphological regularities that are governed by the Semitic templates of Hebrew verbal and nominal morphemes. As such, they are not phonologically motivated from a synchronic view point, since they often correspond to pseudo-phonological distinctions, which are no longer present in the phonetic signal.

Phonologically speaking, this description of spirantization in MH illustrates a case of *Opacity* (Kiparsky 1971, 1973), where the phonological surface forms contain contradicting evidence to the existence of some principle. The consequences of this state of affairs are presented in Adam's (2002) extensive study of opacity and variation in MH spirantization, where variation is taken to be the result of opacity and serves as a sign of grammatical change in progress (see also Bat-El 2001).

Adam (2002) focuses on the morphologically rich, yet highly regular, Hebrew verbal paradigms, where systematic stop-fricative alternations are usually followed by speakers according to MH spirantization norm (under the limits of MH's segmental inventory). However, many speakers often seem to be confused about the status of some alternating obstruent, and as a result they may violate the MH spirantization standard from time to time, thus exhibiting various degrees of variation, both between and within speakers.

According to Adam (2002), there are some consonantal positions within Hebrew verbal paradigms that exhibit higher degrees of variation when occupied by a spirantizable consonant. Adam shows that these varying positions often correlate with specific prosodic configurations, such as the post-consonantal position (when the alternating consonant is the second member of a CC sequence), which is the focus of the following observation.

(4) Post-consonantal variation (alternating obstruent in C_2)

	Production (Left column is normative)			Gloss (Fut-Sg.-Ms.-3rd person)
a.	ya-x**p**or	~	ya-x**f**or	'dig'
b.	yi-s**p**or	~	yi-s**f**or	'count'
c.	yi-k**p**oc	~	yi-k**f**oc	'jump'
d.	yi-n**p**oš	~	yi-n**f**oš	'go on vacation'

Examples (4.a-d) present attested variation among MH speakers with an alternating obstruent at the C_2 position (the second member of a consonantal sequence). In all the examples, the second *root* consonant (i.e. the second consonant of the stem morpheme) is /p~f/. According to the standard requirement it should surface as a stop ([p]) in such post-consonantal environments, yet it often surfaces as a fricative ([f]).

2.3. Is variation free? (rationale of the experiment)

Adam (2002) already established the fact that a higher degree of variation is expected to arise in certain positions that a spirantizable consonant may occupy in the configurations of Hebrew verbal paradigms. As mentioned above, one such position, which is of interest to the following experiment, is the post-consonantal position (i.e. when the alternating obstruent is C_2 in a word medial C_1C_2 sequence). The question that remains open in this respect is whether all alternating post-consonantal C_2 obstruents in Hebrew verbs exhibit the same degrees of variation.

The assumption of the following experiment is that degrees of variation will differ in correlation with the segmental profile of C_1, due to phonotactic reasons, not related to spirantization.

Consider again the examples in (4) above, repeated here below in (5). In all four examples (5.a-d) the same spirantizable obstruent ([p~f]) is in the same post-consonantal position (C_2) of a similar verbal configuration (more details about the verbal configurations in §2.4.1). The main phonological difference among the four examples is the segmental profile of the C_1 consonant: A voiceless fricative in (5.a); a voiceless strident in (5.b); a voiceless stop in (5.c);

and a (voiced) sonorant in (5.d). The following experiment is designed to search for correlations between observed variation trends in C_2 and the segmental profile of C_1.

(5) Post-consonantal variation (emphasis on different C_1)

	Production (Left column is normative)		**C_1**		**C_2**	**Gloss** (Sg.-Ms.-3rd person)
a.	ya-x**p**or ~	ya-x**f**or	fricative	/x/	/p~f/	'will dig'
b.	yi-s**p**or ~	yi-s**f**or	strident	/s/	/p~f/	'will count'
c.	yi-k**p**oc ~	yi-k**f**oc	stop	/k/	/p~f/	'will jump'
d.	yi-n**p**oš ~	yi-n**f**oš	sonorant	/n/	/p~f/	'will go on vacation'

The working hypothesis behind the suggested observation is that when all things are equal except for the profile of C_1, observed variation trends for C_2, that would consistently correlate with C_1's profile, will reflect universal phonotactic tendencies that are otherwise transparent in the grammar. This is known in the phonological literature as The Emergence of the Unmarked (McCarthy and Prince 1994), commonly abbreviated as TETU. The rationale behind TETU follows from constraint-based frameworks such as Optimality Theory (OT). It assumes that in environments where a given language may permit more than one surface form (i.e. in environments that do not invoke any high ranking constraint), the choices that speakers make may reflect the effects of low ranking unmarked/universal constraints, that are otherwise dominated by higher ranking constraints in that language.

Expressed in other terms: Since all the possible varying forms in (5) are legal, and indeed, attested in MH, it is assumed here that any significant and systematic preference towards one form over another, will reflect the phonotactically preferred sequence, due to unmarked universal constraints that generally rank low in MH.

2.4. Experimental design

Since the stop~fricative variation in MH is a phenomenon that occurs in natural speech more than in careful speech, it would have been most desirable to obtain a phonetically transcribed corpus of spontaneous speech in MH. However, due to the lack of such resources on a large enough scale, a production experiment was called for. One major task for an experiment of this kind is to try to elicit productions in a manner that would imitate spontaneous speech, as much as possible. Furthermore, it is crucial to try and eliminate any noise from the target stimuli by keeping everything but the controlled variables (the segmental profiles of C_1 and C_2) as equal as possible, with minimum uncontrolled biases. The following sub-sections (§2.4.1-6) describe the relevant considerations in the choice of stimuli, on phonological, morphological and pragmatic grounds, as well as the procedural details of the production task, which attempts to elicit responses in a pseudo-spontaneous manner.

2.4.1. Materials: Morphological considerations

All of the verbs in Hebrew must fit into one of the five major verbal configurations (*binyan*).[5] Each configuration provides prosodic templates where vocalic patterns combine with consonants that carry the lexical meaning, as they assume their respective positions in given C-slots. The relation between the different configurations is derivational, as they change the basic meaning of a given consonantal "skeleton" (to various extents). Within each configuration, rich inflectional morphology that encodes tense, gender, number and person is achieved by mechanisms that combine affixation with various manipulations of the structural properties of the configuration — the prosodic templates and the vocalic patterns (i.e. mechanisms such as ablaut, which change the vocalic arrangement of the template). This highly regular architecture features some predictable C_1C_2 sequences, where both consonants belong to the base morpheme (not the affixes).[6]

Although relevant CC sequences may appear in all configurations (with full inflectional paradigms considered), only two configurations fulfill the requirements for the experimental design: (1) The configuration features a generally stable production of C_2 fricatives in post-vocalic position; (2) The configuration exhibits stop~fricative variation when C_2 is post-

5. The passive configurations, *huf'al* and *pu'al*, are dependent on their transitive counterparts, *hif'il* and *pi'el* (respectively), and do not count as fully-fledged configurations. Bat-El (2002) argues that these patterns are derived through passivization processes that change the quality of the vowel via melodic overwriting.

6. I disregard cases where one of the consonants belongs to an affix, since they cannot be manipulated.

consonantal. (6) summarizes this for the five vocalic configurations in Hebrew, showing that only *pa'al* (a.k.a. *qal*) and *nif'al* configurations fully fit the criteria.

(6) Status of C_2 in Hebrew verbal configurations in MH

Configuration (*binyan*)	**Citation form**	**Spirantizable C_2 is mostly a stable fricative post-V**		**Spirantizable C_2 often varies post-C**	
pa'al	$\mathbf{C_1aC_2aC_3}$	√	***tafas / *tapas*** **'caught'**	√	***yi-tfos ~ yi-tpos*** **'will catch'**
pi'el	$\mathrm{C_1iC_2eC_3}$	X[7]	**tifes / tipes* 'climbed'	X[8]	**ye-tafsu / ye-tapsu* 'will climb'
nif'al	$\mathbf{ni\text{-}C_1C_2aC_3}$	√	***ti-tafes / *ti-tapes*** **'will get caught'**	√	***ni-tfas ~ ni-tpas*** **'got caught'**
hif'il	$\mathrm{hi\text{-}C_1C_2iC_3}$	√[9]	*he-(ʔ)efir / *he-(ʔ)epir* 'gone gray'	X	**hi-kfic / hi-kpic* 'bounced'
hitpa'el	$\mathrm{hit\text{-}C_1aC_2eC_3}$	X[10]	**hit-kafel / hit-kapel* 'was folded'	X	**yit-kaflu / yit-kaplu* 'will be folded'

While both *pa'al* and *nif'al* are similar in the sense that they hardly ever host novel verbs, which include many loanwords (they are not available for new denominative verbs, which most often take the *pi'el* form), the *pa'al* configuration is more general, i.e. it hosts the largest number of verbs (types and tokens), and it is not considered to reflect any salient semantic function (Berman 1978). This trait of generality of function, which renders it as a default configuration is also shared with the *pi'el* configuration (the currently productive default configuration), which failed to satisfy the previous criteria. Therefore, and in order to maintain things as equal as possible, only the *pa'al* configuration was used in the experiment (see (7)).

7. Non-varying post-V stop due to the pseudo-geminate position (historical position of geminates).

8. Only the last 2 consonants (C_2C_3) in *pi'el* configurations form a sequence.

9. The *hif'il* configuration features post-vocalic C_2 consonants only in a marginal set of marked cases, when C_1 is historically a guttural consonant (e.g. *he-(ʔ)efir* 'gone gray'), excluding /(ħ)→x/ (e.g. *he**x**lim* 'recovered').

10. Non-varying post-V stop due to the pseudo-geminate position (historical position of geminates).

(7) Productivity and functionality of Hebrew verbal configurations

Configuration (*binyan*)	**Citation form**	**Available in novel denominatives**	**Scope of salient semantic functions**
pa'al	$\mathbf{C_1aC_2aC_3}$	**No (√)**	**General (historical default) (√)**
pi'el	$C_1iC_2eC_3$	Yes	General (current default)
nif'al	$\mathbf{ni\text{-}C_1C_2aC_3}$	**No (√)**	**Limited (mainly passives and decausatives) (X)**
hif'il	$hi\text{-}C_1C_2iC_3$	Yes (limited)	Limited (mainly causatives)
hitpa'el	$hit\text{-}C_1aC_2eC_3$	Yes (limited)	Limited (mainly reflexives and reciprocals)

As mentioned earlier (§2.2), there are three alternating stop-fricative pairs in MH — [p~f], [b~v] and [k~x] — and none of them is in complementary distribution. All pairs are opaque due to the effects of loanwords and historical/pseudo-geminates. However, the *pa'al* configuration is generally immune to these effects since loanwords are rarely derived in this verbal configuration, and historically it has no geminate slots (6).

2.4.2. Materials: Phonological considerations

Further reasons for opacity should be attributed to the pairs [b~v] and [k~x] (but not [p~f]) due to the fact that there are [k], [x] and [v] sounds of Hebrew origin that do not alternate even in environments that facilitate systematic alternation in MH. For example, consider the two verbs in Table (I), both are in the *pa'al* configuration with a stable post-vocalic [v] as the second stem consonant of the citation form (in fact, the two verbs are identical in their citation form). In the future tense, when that second consonant is post-consonantal, the [v] sound that is historically [w] never alternates (I.a), while the [v] sound that historically alternates may exhibit variation (I.b).

Table (I) *Differences in behavior of /v/ from different origins*

	Citation form (past Sg.-Ms.-3)	**Future** (Sg.-Ms.-3) (Left column is normative)	**Origin of [v]**	**Gloss**
a.	ta**v**a	yi-t**v**e ~ *yi-t**b**e	Historical /w/ Hebrew letter: <ו>	'plan'/'spin thread'
b.	ta**v**a	yi-t**b**a ~ yi-t**v**a	Historical /v-b/ Hebrew letter: <ב>	'drown'

The [p~f] pair is the only alternating pair that does not feature cases like the one in Table (I), therefore it should be considered as a less "noisy" pair in terms of uncontrolled effects on degrees of variation. To exemplify this last claim, consider example (I.b), where it seems plausible to speculate that due to the phonological similarity with another Hebrew verb (I.a), speakers may show some preference for a post-consonantal stop (*yi-t***b***a*) to avoid confusion by maximizing distinctions. For these reasons, and, again, in order to keep things as equal as possible, only [p~f] alternations were used in the C_2 position of the target stimuli.

2.4.3. Materials: Pragmatic considerations

A preliminary pilot experiment revealed a tendency of high-register/infrequent verbs to prefer the non-normative, non-alternating form, with C_2 fricatives in both post-vocalic (citation form) and post-consonantal (future tense) environments. This tendency seems to promote paradigm uniformity via reduction of alternations in high-register/infrequent verbs (Table II). It is possible to speculate that the reasons for this may be related to the fact that unknown or infrequent verbs are hardly used in future conjugations, to the extent that they sound alien in the future tense. In such cases, the normative sound alternation is disfavored as it further increases the alien-hood of such rare word forms.

Table (II) *Infrequent/ high-register verb*[11]

	Citation form (past Sg.-Ms.-3)	Future (Sg.-Ms.-3)	Results	Gloss
a.	*la**f**at* / **la**p**at*	*yi-l**f**ot* > *yi-l**p**ot*	15 out of 22 (68%) preferred *yi-l**f**ot*	'grasp tightly'
b.	*sa**v**ar* / **sa**b**ar*	*yi-s**v**or* > *yi-s**b**or*	13 out of 22 (59%) preferred *yi-s**v**or*	'think'

Be that as it may, it seems justified to eliminate infrequent verbs from the target stimuli to avoid the attested noise. However, since reliable accounts on frequency of types and tokens in spoken MH are hard to obtain, a measurement of register for a list of *pa'al* verbs was obtained using a survey (an online questionnaire), which was passed among 41 colleagues, all with some background in linguistics.[12] Eventually, only the verbs that more than 90% of participants considered as belonging to *regular* register passed as valid targets.

Lastly, the pilot experiment revealed a noisy trend with bi-consonantal verbs, also known as *weak verbs*. This set of verbs is irregular as most Hebrew verbs have 3 stem consonants throughout the paradigm. The trend in the case of bi-consonantal verbs was towards a normative C_2 stop in post consonantal positions, a bias which does not seem to be phonologically motivated by phonotactics (Table III).

Other considerations that do not directly involve the segmental profiles of verbs have been shown to be characteristic of weak verbs in MH. For example, Zadok (2012) shows that weak verbs in MH tend to exhibit morphological variations that suggest, among other things, predictions for the final-state of these morphological changes, which involve paradigm shifts. Here, as well, phonological opacity that arises from differences in segmental inventory (between BH and MH) drives this variation in weak verbs. More crucially for the current discussion, it further justifies the treatment of this group of verbs as irregular and therefore "noisy".

11. The arrow sign (>) indicates attested preference. Results were taken from the preliminary pilot experiment.

12. Descriptive statistics of the 41 survey participants: **Gender**: 63% females and 37% males; **Age**: 61% were 26-36, 17% were 36-45, another 17% were above 46 and 5% were 18-25; **Education**: approx. 1/3 undergraduate students, 1/3 graduate students and 1/3 PhD candidates or above.

Table (III) *Bi-consonantal verbs*

	Citation form (past Sg.-Ms.-3)	Future (Sg.-Ms.-3)	Results	Gloss
a.	*cafa* / **ca**p**a*	*yi-cfe* < *yi-c**p**e*	22 out of 22 (100%) preferred *yi-c**p**e*	'observe'
b.	*sava* / **sa**b**a*	*yi-sva* < *yi-s**b**a*	20 out of 22 (91%) preferred *yi-s**b**a*	'be satiated'
c.	*kava* / **ka**b**a*	*yi-kva* < *yi-k**b**a*	18 out of 22 (82%) preferred *yi-k**b**a*	'determine'

2.4.4. Materials: Targets and fillers

With the elimination of bi-consonantal and high-register verbs, 9 valid *pa'al* verbs with *p~f* as their second consonant were incorporated in the stimuli. These experimental targets reflect a variety of C_1 obstruents (Table IV): 4 with C_1 stops, 3 with C_1 strident fricatives, 1 with a C_1 non-strident fricative, and 1 with a (strident) affricate. All tokens feature a voiceless C_1, except for *dafak*, in which /d/ is regularly expected to assimilate in voicing with an immediately following voiceless [p~f] consonant (i.e. /yi**d**Pok/ → [yi**t**Pok], where P = p~f).[13]

Table (IV) *List of target verbs sorted by type of C_1*

C_1 type:	**Stop**	**Strident** (fricative)	(non-strident) **Fricative**	(strident) **Affricate**
Verb tokens (citation form):	***t**afas* 'catch' ***t**afar* 'sew' ***d**afak* 'knock' ***k**afac* 'jump'	***š**afax* 'spill' ***s**afar* 'count' ***s**afag* 'absorb'	***x**afar* 'dig'	***c**afar* 'honk'

The target verbs were inserted in sentential frames. These sentences were created with minimal consonantal sequences within and across words, and with the lexical, non-metaphoric meanings of the verbs, since metaphoric uses of verbs tend to reject normative forms, as in the verb *yidfok~yid**p**ok* 'will knock', which does not seem to appear as the normative *yid**p**ok* with its metaphorically derived meaning, 'screw'-coll. See also

13. This is a simplified view of voicing assimilation in MH. However, given that the initial voiced obstruent is expected to assimilate (lose its voicing) in this sequence, this scenario presents fewer exceptions to a regular voicing assimilation process (Mizrahi, to appear). For more on voicing assimilation in MH see also Bolozky (1978), Malachi and Horvath (1978) and Kreitman (2010).

yaxfor~yaxpor 'will dig' in the metaphoric sense of 'will talk someones head off', where the normative form *yaxpor* does not seem to fit due to some sort of register conflict.

(8) a. בשבוע שעבר הוא **חפר** את הבור
*bešavua šeavar (h)u **xafar** et (h)a-bor*
'Last week he dug the hole'

b. עידו **דפק** היום על הדלת
*ido **dafak** (h)ayom al (h)a-delet*
'Ido knocked today on the door'

Filler sentences were added in a 2:1 ratio such that there were 2 fillers for each target. The filler sentences never include a verb in the *pa'al* configuration to disguise the relative high frequency of the target *pa'al* verbs among the stimuli. The list was arranged in a pseudo-random order and presented in two opposite orders.

2.4.5. Procedure

Participants were instructed to read aloud sentences that were presented orthographically on a full 13" computer screen. In order to minimize effects of elicitation tasks, which include certain reading intonations and more careful speech with attention to linguistic norms, the sentences were not to be read as is.

All sentences were written in the past or present tense (where C_2 in the target stimuli is a stable post-vocalic fricative), yet participants were instructed to read the sentences to themselves and then utter them in the future conjugation (where C_2 is post-consonantal and tends to vary), which they had to construct "by heart".

Since tense inflections are inherent to verbs they are rather easily conjugated as the task requires. In order to further divert participants' attention from the verbs themselves, different tense complications were added to all target sentences and most of the filler sentences. These complications included the following types (Table V):

Table (V) *List of conjugation complications*

	Type of complication	Examples	
a)	Adverbs denoting past or present time.	i. **בשבוע שעבר** הוא חפר את הבור *bešavua šeavar (h)u xafar et (h)a-bor* '**Last week** he dug the hole'	ii. עידו דפק **היום** על הדלת *ido dafak (h)ayom al (h)a-delet* 'Ido knocked on the door **today**'
b)	Embedded clauses with another internal tense inflection.	i. בני צפר על האוטו **שעצר** *beni cafar al (h)a-oto še-acar* 'Beni honked at the vehicle **that stopped**'	ii. הקרש **שמחזיק את הארון** נשבר *(h)a-kereš še-maxzik et (h)a-aron nišbar* 'The board **that keeps the cabinet** broke'
c)	Nouns that are similar to present tense verbs (participles) or past tense verbs.	i. הוא **שומר** בחברת שמירה *(h)u šomer be-xevrat šmira* 'He **guards/is a guard** in a guarding company'	ii. הוא **כתב** לענייני חוץ *(h)u katav le-inyaney xuc* 'He **wrote/is a reporter** of foreign affairs'
d)	Conjunctions with two different tenses.	i. **בשנה שעברה** הפרח הזה **נבל** אבל **היום** הוא **פורח** *ba-šana še-avra (h)a-perax (h)aze naval aval (h)ayom (h)u poreax* '**Last year** this flower **withered** but **today** it is **flourishing**'	
e)	Present tense copular sentences with no overt copular.	i. נוני **(∅)** ממש מעצבן *noni mamaš meacben* 'Noni **(is)** really irritating'	

These complications contributed greatly to the fact that participants invested most of their efforts in forming the full sentences in future tense, rendering the verbs among the least challenging (and therefore less salient) aspect of the stimulus.

2.4.6. Participants

The experiment was conducted on 24 participants, 14 males and 10 females. The mean age of participants was 30.6 (from 9 to 60 year olds). The two opposite list orders were split evenly among the 24 participants. In the analysis of the results, no significant effects were found for list order, gender or age (verified with non-parametric Kruskal Wallis tests). A marginal effect was found between participants' age and the target *safag*. Apparently, the very few productions of a post-consonantal fricative in *yisfog* came from the younger edge of the age spectrum.

2.5. Results

The participants' responses were recoded to a computer, using a standard dynamic microphone (Shure SM58) and a semi-professional audio interface (Metric Halo MIO2882), using standard CD quality A/D conversion (44,100Hz, 16 bit). When analyzing the recordings (on the basis of audition), values were assigned to a spreadsheet, reflecting the production of post-consonantal C_2 in all target sentences such that 0 (zero) reflects a production of C_2 stop and 1 reflects a production of C_2 fricative. Eventually, verbs with higher scores are the ones that more participants uttered with a post-consonantal C_2 fricative, while low scores (below 0.5) reflect more post-consonantal C_2 stop productions (the normative form). The results for the 9 target verbs form 3 significantly distinct groups (see Figure i and Table VI).

Figure (i) *Mean values of post-consonantal C_2 productions (0=stop; 1=fricative)*

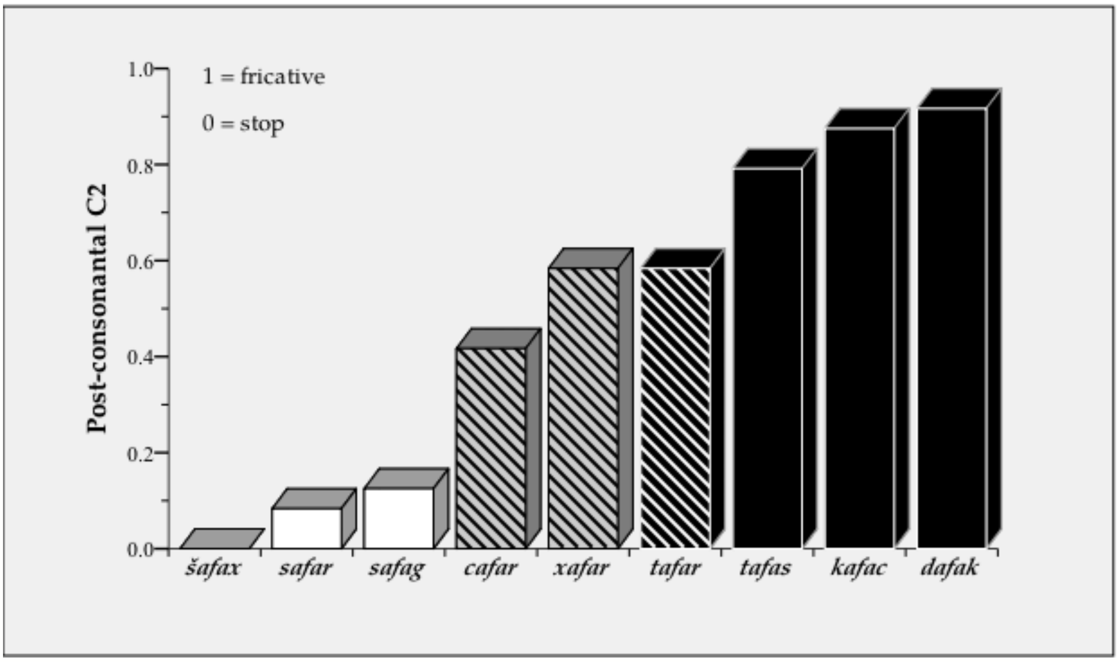


Table (VI) *Summary of results*

Group	Statistics[14]	Conclusion
I. ***d**afak* ***k**afac* ***t**afas*	Three of the four verbs with C_1 stops (***t**afas*, ***d**afak* and ***k**afac*) are not significantly different from each other ($\chi^2(2) = 3.500$, $p = .174$), while they are all significantly different from chance ($p < .007$). **The trend in this case is to prefer C_2 fricatives when following stops.**	**[stop]-[fricative]** > [stop]-[stop] (e.g. *yit**f**os* is better than *yit**p**os*)
II. ***š**afax* ***s**afar* ***s**afag*	The group of C_1 strident fricatives (***š**afax*, ***s**afar* and ***s**afag*') are not significantly different from each other ($\chi^2(2) = 4.667$, $p = .097$), while they are all significantly different from chance ($p < .001$). **The trend in this case is to prefer C_2 stops when following strident fricatives.**	[strident]-[fricative] < **[strident]-[stop]** (e.g. *yis**p**or* is better than *yis**f**or*)
III. *xafar* *cafar* ***t**afar*	The one verb with a C_1 fricative (*xafar*), as well as the one with a C_1 affricate (*cafar*), and one of the four C_1 stops (*tafar*) were found to be not significantly different from each other ($\chi^2(2) = 3.556$, $p = .169$), nor from chance ($p > .541$). **No observable trend.**	[affricate]-[stop] ~ [affricate]-[fricative] [fricative]-[stop] ~ [fricative]-[fricative]

Given an interpretation that stops prefer a following fricative (group I) while strident fricatives prefer a following stop (group II), the large degree of variation attested with the ("neutral") group (III) is expected with the affricate ([c]), which embodies characteristics of both stops and stridents (hence split between opposite trends), as well as with the non-strident fricative ([x]), which lacks any of the above characteristics (hence shows no clear preference).

Note that the "misbehaved" verb with C_1 stop (*tafar*), which patterns with the neutral group (III), is, in fact, not significantly different from *tafas*, the lowest ranking member in group (I). However, the same is also true for *xafar*, which received the same score as *tafar,* and both were found to be not significantly different from chance.

While this issue remains unresolved, it does not overshadow the main trends that are attested in groups (I) and (II) regarding the influence of occlusion (in stop-initial sequences)

14. Group patterning were verified with Related-Samples Cochran's Q tests, while verifications of difference from chance were done using a One-Sample Binominal test.

and stridency (in strident-initial sequences) on the preference for a stop vs. fricative in C_2. The following analysis (§3) focuses on the trend revealed in group (I), to prefer a C_2 fricative when following a C_1 stop.

3. Analysis

One possibility to explain the attested trend for preferred C_2 fricatives when following C_1 stops (group I) is based on the notion of *Alignment* (McCarthy & Prince, 1993).

(9) Align-L(Stop,σ)

For every Stop consonant, there is a σ (syllable) such that the left edge of Stop coincides with the left edge of σ

If it can be shown that an unmarked Align-Left constraint drives stops to be left-aligned with syllable edges (i.e. stops should be onsets), we would be in a position to claim that a sequence of two stops, such as in *yi**tp**os*, must include one violation of this alignment constraint, while a sequence with one stop (e.g. *yi**t**fos*) may satisfy it, provided that the sequence syllabifies as a complex onset. Table (VII) uses OT notations to illustrates this example with candidates that differ in segmental qualities of C_2 (VII.a-b vs. VII.c-d) and syllabification of the CC sequence (VII.a,c vs. VII.b,d).

Table (VII) ***Align-L(Stop,σ)*** *with future conjugation of [tafas] 'will catch'*

/yitPos/	**Align-L (Stop,σ)**
a. [yi**t**.pos]	*!
b. [yi.t**p**os]	*!
c. [yi**t**.fos]	*!
d. ☞ [yi.**t**fos]	

A sequence of two stops (VII.a-b) is disfavored since one of the stops cannot be properly aligned with the left edge of a syllable. A sequence containing only one stop (VII.c-d) will be favored provided that the medial sequence is syllabified as a complex onset (VII.d), whereby the stop consonant is properly left-aligned (compare with (VII.c)).

3.1. Segmental-prosodic alignment: Theoretical account

McCarthy & Prince (1993) show that a simple set of alignment constraints between segments (consonants and vowels) on the one hand, and syllables on the other, can cover a vast range of principles in syllable theory, that are otherwise stated with construction-specific constraints such as **Onset**, ***Coda**, ***Diphtong** and **CodaCondition** (Itô 1986, 1989). A key element in traditional alignment constraints is that their logical statement works such that the first argument is quantified universally ("every X") and the second argument is quantified existentially ("some Y"). Therefore, **Align-L(σ,C)** is equivalent to **Onset**, since it requires that *every syllable* be left-aligned with *a consonant* (i.e. all syllables must have onsets), while **Align-L(C,σ)** subsumes **CodaCondition**, since it requires that *every consonant* be left-aligned with *a syllable* (i.e. all consonants must be mapped to some onset position). In order to fully account for different coda conditions that different languages impose on coda distribution, Itô and Mester (1999) rely on the built-in architecture of a "family of constraints", such that **Align-L(C,σ)** is a general statement, which encapsulates a fixed typological hierarchy of more specific statements, defined by consonantal features in the place of the first argument, C. For example, Itô and Mester (1999) suggest replacing McCarthy and Prince's (1994) ***[pharyngeal])$_{\sigma}$** construction-specific variant of **CodaCondition** for Biblical Hebrew and Bedouin Arabic, with the alignment constraint **Align-L([pharyngeal],σ)**, which is a member of the family of **Align-L(C,σ)**.

Given the hierarchical typology of **Align-L(C,σ)**, the alignment constraint suggested here (9), is similar to **Align-L([pharyngeal],σ)** in that it specifies the features of the first general argument (**C**). The main difference being the type of specified feature: The feature **[pharyngeal]** describes Place of Articulation while the category **Stop** describes Manner of Articulation (the following section motivates the use of **Stop** as the constraint's first argument). Since it is widely accepted that stops are the least marked onset consonants, it should be relatively easy to further justify a hierarchical typology in which **Align-L(Stop,σ)** dominates **Align-L(Nasal,σ)**, and so forth.

3.2. Articulatory support

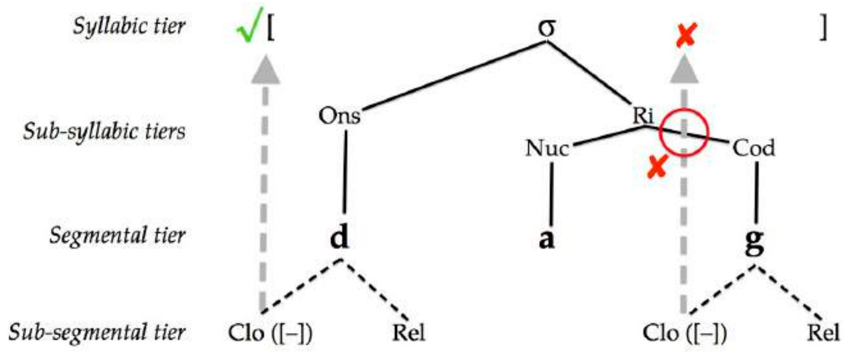
The fact that stops block the airflow within the stream of speech is captured in the phonological literature, to some extent, with the binary feature [±continuant], where stops are [–continuant]. This value is also shared by nasals (and sometimes laterals) that are, indeed, released with a burst, in manners that resemble the release of stops, yet they do not block the airflow at their closure node like stops do. Nasals and laterals allow continuant airflow at their closure (even if it is restricted to lateral release or diverted to the nasal cavity), and unlike stops they have the cross-linguistically attested distribution and behavior of sonorants (e.g. they rarely appear in the beginning of complex onsets, they can often fill a nucleus position and voiceless nasals/laterals are highly marked).

Within the binary feature system it is possible to distinguish the natural class of stops with a combination of two unrelated features, [–continuant] and [–sonorant], but that formal fact disregards an important articulatory feature, which is pivotal for the following description, in which the difference between the sub-segmental features *closure* and *release* plays a crucial role in determining the direction of syllabic alignment for stops, and their preferred phonotactic configurations.

To some extent, the above is in line with Steriade's (1992, 1993) *oral aperture nodes*. The aperture nodes replace binary features, such as [±continuant], by representing the stricture of the oral tract. This corresponds to closure and release of stops much in the same way that I propose, such that the closure node is represented as A_0 ('aperture zero') and the release is represented as A_{max} ('maximal aperture'). However, my proposal differs, among other things, in that it does not represent the stricture of the oral tract, but, rather, the stricture of the vocal tract, which includes the nasal cavity as well as the oral. The consequences of these differences are apparent when dealing with nasals, since in my model nasals have an open closure node ([+closure]) unlike stops, and a [–continuant] release, just like stops.

3.2.1. Onset vs. Coda stops

Figure (ii) *Prosodic nodes and sub-segmental alignment scheme for [dag] 'fish'*



Legend: **[]** = syllabic boundaries; **Ons**(et), **Ri**(me), **Nuc**(leus), **Cod**(a), **Rel**(ease), **Clo**(sure)[15].

Figure (ii) shows a sketch of a CVC syllable, occupied by stops in its two consonantal positions (demonstrated by the Hebrew word *dag* 'fish'). The sub-segmental tier at the bottom shows the points of *Closure* and *Release* of the two stops. The dashed vertical grey arrows show the alignment between sub-segmental closure nodes and boundaries at the syllabic and sub-syllabic tiers.

Assuming that the release of [g], at coda position, is included within the margins of the CVC unit, its closure node aligns within the rime, blocking the airflow between the vowel in the nucleus position and the release of the stop in coda position. In onset position, on the other hand, [d] can align its closure node with the left edge of the syllable.

Figure (ii) shows that a stop consonant in coda position is problematic for two different reasons: (1) It is not aligned with any syllabic boundary at the syllabic tier; (2) It breaks the rime in the middle at the sub-syllabic tier. This description phonetically motivates the strong tendency of stops to align left with a syllable (i.e. to assume the onset position), but note that in the CVC example in Figure (ii), the onset stop ([d]) aligns its closure node with the left edge of a syllable provided that this CVC syllable is either word-initial, or better yet, phrase-initial. The following paragraphs deal with various scenarios where an onset stop is in word-medial positions.

15. **Clo([–])** = closure node in full blockage mode (i.e. [–closure]).

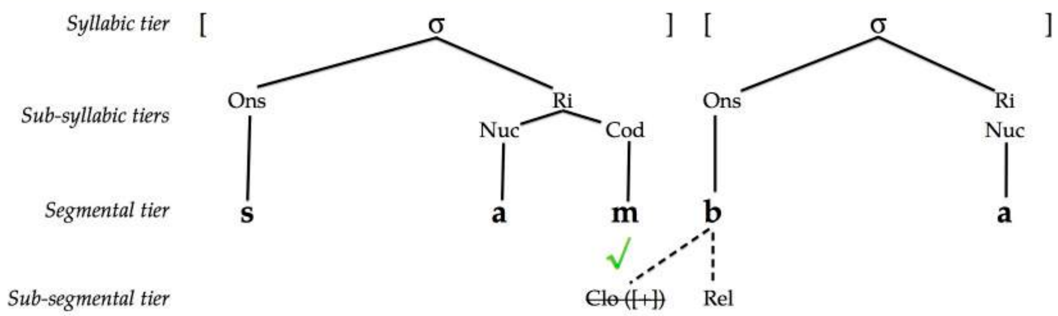
3.2.2. Medial onsets: Post-vocalic vs. homorganic post-consonantal stops

Figures (iii)-(vi) demonstrate a near-minimal set of disyllabic words, with emphasis on the onset of the second, unstressed syllable.[16] The word in Figure (iii), *samba*, demonstrates a case where the onset stop ([b]) is in a post consonantal position. More specifically, it is in a homorganic sequence with the preceding coda ([m]). Homorganic sequences, which share a common place of articulation, often take this general form of NC ([Nasal]–[Stop]) and are often considered, together with geminates, as a single unit that is "doubly place-linked" in nonlinear representations (Steriade 1982, Itô 1986, 1989). Padgett (1994) proposes that in homorganic clusters the cluster-initial nasal/lateral shares its closure with the following consonant, based on a feature geometry where stricture is dominated by Place node.

This is reflected in the articulatory description in Figure (iii), where the nasal in coda position "takes over" the closure portion of the stop, which, in turn, "takes over" the release portion of the nasal (i.e. there is a division of labor such that the nasal is realized only on the closure node and the stop is realized only on the release node). It is widely accepted to claim in such cases that the second syllable starts with the release of the stop. Therefore, only the release node is aligned left, but this does not create a problem since the preceding closure node of a stop in homorganic sequences is not fully blocking the airflow (considering that nasal cavity airflow does not constitute an airflow blockage).

Figure (iii) *Prosodic nodes and sub-segmental alignment scheme (post-consonantal stop)*

Stop in homorganic sequence: [ˈsam.**b**a] 'Samba'

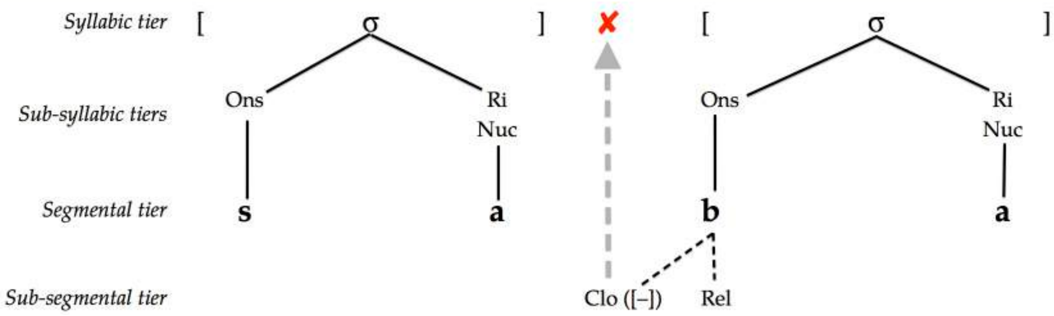


16. Stress location is not assumed to affect the basic articulatory synchronization of speech events in a relevant way. Words in the examples are arbitrarily chosen with a trochee foot to keep things as equal as possible.

The word in Figure (iv), *saba* 'grandfather', differs from the word in Figure (iii) only in the lack of a nasal. The stop, [b], appears in onset position between two vowels. Here as well, the second syllable starts with the release of the stop (imagine, for example, that a speaker puts a pause between the two syllables—the beginning of the second syllable will be clearly aligned with the audible release of the stop, not the silent pause that precedes it). The silent portion that articulatorily corresponds to the blockage of the closure node, precedes the release, and, therefore, precedes the syllabic boundary, thus failing to align with it. Note, however, that unlike the two violations that a stop incurs when in coda position (Figure ii), the mis-alignment of intra-vocalic onset stops should be regarded as a "softer" violation since they do not break any sub-syllabic constituent, such as the rime, in the middle.

Figure (iv) *Prosodic nodes and sub-segmental alignment scheme (intra-vocalic stop)*

Stop in VCV: ['sa.**b**a] 'grandfather'



This alignment problem is unique to stops (or to [–closure] segments). Figures (v)-(vi) demonstrate how an intra-vocalic onset with a non-blocking closure node ([+closure]), whether it is a sonorant (Figure v) or a fricative (Figure vi), manages to align its closure node with the left edge of the second syllable (again, it is helpful to imagine a speaker putting a pause between the two syllables—the second syllable begins with the audible [+closure] node of the onset, before the release).

Figure (v) *Prosodic nodes and sub-segmental alignment scheme (intra-vocalic sonorant)*

Nasal in VCV: [ˈša.**m**a] 'there'

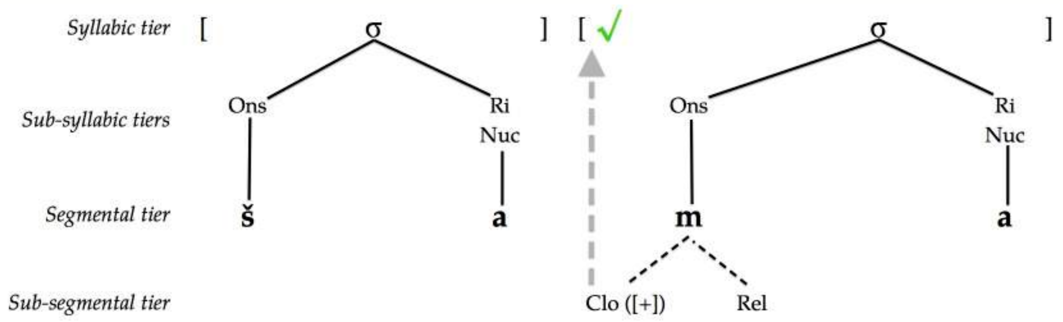
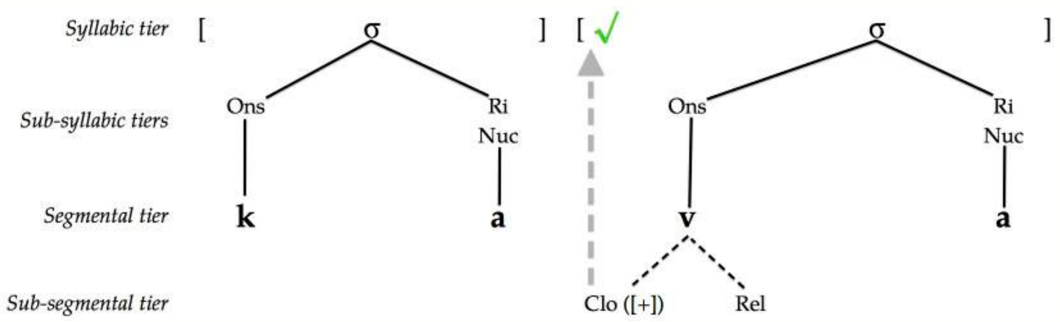


Figure (vi) *Prosodic nodes and sub-segmental alignment scheme (intra-vocalic fricative)*

Fricative in VCV: [ˈka.**v**a] 'cava' (generic brand name of popular Spanish sparkling wine)



To demonstrate the idea that the closure node of a stop consonant is within the margins of a preceding coda it is helpful to consider word/phrase-final coda stops. In languages that permit such distribution of coda stops, it appears that they are often unreleased (or, more accurately, articulated without a perceptually audible release) in word/phrase-final positions. The transition of formants from the nucleus to the closure node of a stop often suffices in order to perceptually recover the place information of the inaudibly released stop, even though the closure node of a stop is, in itself, inaudible (see Abramson and Tingsabadh's 1999 account of English and Thai final stops and Iverson's 2006 account of final stops in Korean loanwords). This case is even stronger for unreleased word/phrase-final sonorant [–cont] consonants such as nasals and laterals, which, unlike stops, have the capacity for audible information in their closure node, and are therefore more easily recoverable without an audible release.[17]

17. Note that nasals are more informative about their place of articulation in their release node rather than their

This tendency to avoid an audible final release of [–cont] consonants should be related to the fact that their release is characterized by a sudden burst of energy which is best suited to open a (syllabic) unit such that following segments will retain or increase the airflow pressure towards the following nucleus (in line with optimal sonority profiles).[18] Interestingly, in some languages there is a process of aspiration that occurs on final coda stops (see the discussion in Goad and Brannen 2003 for an overview of epenthesis and aspiration in word-final stops, with children acquiring language, as well as some adult grammars). This tactic satisfies the requirement for a *faithful* audible release of stops, while marking them as final (i.e. not opening a following unit) or, alternatively, reflecting the syllabification of final stops as onsets.

3.2.3. Heterorganic post-consonantal stops

Figure (iii) above demonstrated one specific case of stops in post-consonantal positions—a case of a homorganic onset stop (*sam.**b**a*). Since nasals in MH, as well as cross-linguistically, often assimilate their place of articulation with an immediately following stop, I will assume here that any NC sequence is, at least potentially, homorganic. This still leaves open the alignment status of stops in post-consonantal positions, when the preceding C_1 is a heterorganic fricative, liquid or glide.

We know from spirantization phenomena that a stop may spirantize not only post-vocalically but sometimes also when following (or between) sonorant consonants, such as glides and even liquids and nasals (10). This evidence suggests that stops do not perfectly align their closure node when following a heterorganic consonant, since in such cases they may exhibit similar behavior to stops in post-vocalic environments (i.e. they may spirantize).

---

closure node, but they are highly informative in their release node with regards to their (nasal) manner of articulation. Of course, the general recoverability of word/phrase-final unreleased [–cont] consonants also benefits from contextual semantic and pragmatic cues, as well as syntactic limitations on possible words. The phonological cues described here are just another element of inherently redundant grammars, where redundancy is a trait that promotes recoverability (see Abrahamsson's 2003 paper on redundancy and recoverability of word-final codas in Chinese learners of L2 Swedish).

18. I elaborate on the various sonority-based principles in §3.5 below.

(10) Biblical Hebrew[19]

a. /ha:y**t**á:/ → [ha:y.**θ**á:] 'be' (Sg.-Fm.-3rd person, past)

Spanish[20]

b. /el beso/ → [el βeso] 'the kiss'

The neutralization of airflow blockage is contingent upon the preceding (or surrounding) airflow intensity, among other things. A highly disrupted airflow, such as in fricatives, is minimally distant from a fully blocked airflow, and, evidently, a fricative usually does not suffice in triggering spirantization (i.e. stops more rarely spirantize when following fricatives). Vowels, on the other hand, are maximally distant from a fully blocked airflow, and, apparently, they do suffice in triggering spirantization. In line with this description, sonorant consonants, that are mid-distant from a fully blocked airflow, may or may not suffice in triggering spirantization.

In the following sections that deal with spirantization processes I will ignore this complexity by describing only cases where the triggering environment is vocalic. In some cases I avoid this complexity by adopting the solution paved by Prince (1975), where a post-nucleus (rather than post-vocalic) environment is defined as the triggering environment. A post-nucleus environment is considered to subsume both post-vocalic and post-sonorant spirantization processes (considering that sonorant consonants that trigger spirantization are, like vowels, syllabified within the nucleus of the preceding syllable, not its coda).

To conclude, it appears that only in certain syllabic positions (onset) and structural configurations (phrase-initial position and C_2 of a homorganic sequence), stops do not mis-align their closure node, and, as a result, remain more immune to alternation (again, this description discards the contribution of preceding airflow intensity to this issue of sound-change "immunity"). The underlying assumption is that syllables are units that optimally regulate airflow sequences such that a full blockage is limited to configurations where it is optimally aligned.

19. Adapted from Idsardi (1998), citing Ezek. 21:17.

20. Adapted from Baković (1994).

3.3. Empirical support

Going back to the notion of spirantization as a natural process that compromises the occlusion (or airflow blockage) of stops in certain environments, it is of interest to note that pre-vocalic positions never constitute a sufficient condition for spirantization. A natural process such as the one schematized by the rule in (11) is unlikely, and to the best of my knowledge, not attested cross-linguistically.

(11) [–son] → [+cont] / __V (**Unlikely**)

These empirical facts about natural spirantization are in-line with the theoretical alignment constraint and the articulatory-based description proposed here, assuming a phonetic motivation for the weakening of stop's occlusion in post-vocalic positions. However, in order to adequately account for natural spirantization processes with the proposed alignment devices, further elaboration is required. In the following section (§3.4) I will demonstrate that, and show the advantages of the proposed alignment constraint over previously used construction-specific devices in describing the cross-linguistically preferred/unmarked onset consonant.

3.4. Theoretical benefits of ALIGN-L

So far, I've shown that the proposed constraint in (9), **ALIGN-L(Stop,σ)**, is phonetically motivated and can be naturally derived form McCarthy & Prince's (1993) **ALIGN-L(C,σ)**, which they originally proposed in order to cover various phenomena that were previously handled with the construction-specific **CODACONDITION** constraint (see also Itô and Mester 1999, for extensive overview of the alignment schema coverage of coda conditions). The relationship between the two alignment constraints was defined by the notion of a "family of constraints", utilizing the built-in hierarchical typology of Optimality Theory constraints. This was achieved by further specification of the first argument, **C**(onsonant), with the manner feature **Stop**. (12) illustrates the relevant underlying hierarchy, based on Adam's

(2002) demonstration of the hierarchy of sonority values in onset position, where C is specified for manner.[21]

(12) <u>Hierarchy of manner-specified C, derived from Align-L(C,σ)</u>

ALIGN-L:

(Stop,σ) » **(Fricative,σ)** » **(Nasal,σ)** » **(Liquid,σ)** » **(Glide,σ)**

The following sub-sections will show another specification of the first argument of an **ALIGN-L(C,σ)** constraint (motivated by the articulatory description in §3.2 above), where sub-segmental nodes are also considered in order to cover natural spirantization processes (§3.4.1). I will also show the derived typology of this proposal (§3.4.2) and its advantages in providing a more elegant answer to the following puzzle: *which consonant is the least marked consonant in a VCV environment?* (§3.4.3).

3.4.1. Accounting for natural spirantization

Languages that exhibit natural spirantization processes may condition the underlying stop consonant with various segmental features. Indeed, different combinations are attested, where some languages limit spirantizable stops by voicing (e.g. voiceless stops do not alternate in Spanish) and/or places of articulation (e.g. emphatic stops do not alternate in BH). Furthermore, the triggering environment for spirantization may also vary cross-linguistically. A post-vocalic position is a necessary condition, which may be sufficient to trigger spirantization in languages like Biblical Hebrew (Table VIII.a), while a pre-vocalic position is never sufficient for spirantization (VIII.b). However, the environment defined by the rule in (VIII.c), where the stop consonant appears between two vowels, is always sufficient in languages that permit spirantization.[22]

21. Adam (2002, p. 144) bases this common hierarchy on sonority-based principles following Steriade (1982), Vennemann (1988) and Clements (1990). She formally defines this hierarchy as follows: *σ[GLIDE » *σ[LIQUID » *σ[NASAL » *σ[FRICATIVE » *σ[STOP.

22. For simplicity's sake, I describe only vocalic segments as the relevant speech sounds in the triggering environment for spirantization. In reality, also consonants may suffice for spirantization in some languages and even in some particular cases of Biblical Hebrew (Idsardi 1998).

Table (VIII) *Triggering environments for natural spirantization*

	Spirantization Rule (schematic)	**Triggering condition**
a.	[–son] → [+cont] / **V**__	Necessary condition
b.	[–son] → [+cont] / __**V**	Insufficient condition
c.	[–son] → [+cont] / **V**__**V**	Sufficient condition

The case of VCV environments (VIII.c) is especially interesting since only one syllabification option is commonly assumed in that scenario. The consonant between two vowels presumably syllabifies as the onset of the second syllable, which takes the following vowel as its nucleus (V.CV, not *VC.V). Hence, it is clear that in languages that exhibit spirantization, stops may alternate not just in coda positions, but in onset positions as well.

This fact does not seem to be covered by the proposed alignment constraint, **ALIGN-L (Stop,σ)**, since it does not target onset stops as illformed (i.e. it does not rule out forms like **ka.pac* 'jumped'). However, an elaboration of **ALIGN-L(Stop,σ)**, which would cover the facts of spirantization, is straight-forwardly available if we consider it as a general constraint that can be further specified with the sub-segmental manner feature, [–closure], to represent the airflow blockage of stops' closure node, in-line with the articulatory description presented in §3.2 above.

(13) ALIGN-L([–closure],σ)

For every [–closure] (closure portion of a stop consonant), there is a σ (syllable) such that the left edge of [–closure] coincides with the left edge of σ

This formal form of the more specified constraint allows languages that permit spirantization to be more strict in their demand to not just align their stops with syllables, but also to align stops in proper configurations, where their closure node is not mis-aligned.

For example, consider the Spanish word for 'finger', *dedo*, which is pronounced in most dialects with the second stop spirantized ([de.ðo]). That second stop, which appears between two vowels, does not align its closure node with a syllable, although it is in the onset position of the second syllable (comparable with *sa.**ba*** from Figure (iv) above).

Tableaux (1-3) illustrate this example and two others, showing how the correct candidates win with a simple interplay of the family of **ALIGN-L(C,σ)** constraints (14).

(14) ALIGN-L(Stop,σ) » **ALIGN-L([–closure],σ)**

The relevant fixed hierarchy that the family of alignment constraints underlies (14), outranks the faithfulness constraint **IDENT[Stop]**, a variant of the standard **IDENT(F)** constraints (McCarthy and Prince 1995), which bans underlying stops from surfacing with other manners of articulation (e.g. ban an alternation of stops into fricatives). Tableau (2) also features the markedness constraint **SCL** (**S**yllable **C**ontact **L**aw, Murray and Vennemann 1983, Vennemann 1988), to eventually choose a more properly syllabified candidate (the exact ranking of **SCL** in relation with all the other constraints is, in itself, irrelevant to the current analysis).[23]

Tableau (1) *Spanish: dedo 'finger'*

/dedo/	**ALIGN-L (Stop,σ)**	**ALIGN-L ([–closure],σ)**	**IDENT[Stop]**
a. [de.do]		*!	
b. [ðe.do]		*!	*
c. [ðe.ðo]			**!
d.☞[de.ðo]			*

None of the candidates (1.a-d) violates **ALIGN-L(Stop,σ)** since all stops are in onset positions, yet candidates (1.a-b) violate **ALIGN-L([–closure],σ)** due to the stop in post-vocalic mid-word position, which does not align its closure node with the left edge of a syllable. Eventually, the winning candidate (1.d) is the one that minimally violates the faithfulness constraint, **IDENT[Stop]** (compare with (1.c)).

23. More on the SCL, and other sonority-based principles, in §3.5. below.

Tableau (2) *Spanish: cubrir 'cover'*

/kubrir/	**ALIGN-L (Stop,σ)**	**ALIGN-L ([–closure],σ)**	**IDENT[Stop]**	**SCL**
a. [kub.rir]	*!	*		*
b. [ku.brir]		*!		
c. [kuβ.rir]			*	*!
d. ☞ [ku.βrir]			*	

Candidate (2.a) violates **ALIGN-L(Stop,σ)** due to the syllabification of a stop consonant in coda position, and both candidates, (2.a-b), violate **ALIGN-L([–closure],σ)** since they fail to left-align the closure node of the post-vocalic stop [b]. Candidates (2.c-d) vacuously satisfy the alignment constraints since they feature a fricative rather than a stop (therefore, they equally violate **IDENT[Stop]**). Eventually, only (2.d) satisfies **SCL**.

Tableau (3) *Spanish: donde 'where'*

/donde/	**ALIGN-L (Stop,σ)**	**ALIGN-L ([–closure],σ)**	**IDENT[Stop]**
a. ☞ [don.de]			
b. [ðon.de]			*!
c. [ðon.ðe]			*!*
d. [don.ðe]			*!

The 2 stop consonants of candidate (3.a) do not violate any of the alignment constraints since one of them is phrase-initial and the other one is homorganic (comparable with *sam.ba* from Figure iii above). Since all stops are properly aligned, the winning candidate (3.a), which does not feature any alternation of stops into fricatives, also does not violate **IDENT[Stop]**, while all other candidates (3.b-d) do.

Baković (1995) proposed a comparable alignment constraint, utilizing Steriade's (1992, 1993) *oral aperture nodes*, which he termed STRONG ONSET. The formal form of this constraint is ALIGN-L(σ,A_0) which requires that every syllable will be left-aligned with an oral closure. Note that the two aligned categories, that of the prosodic category (syllable) and that of the segmental category (aperture zero), are in the opposite direction in this proposal since

Baković (1995) assumes that the underlying forms in Spanish spirantization are fricatives (or more accurately, approximants) and they surface as stops when they can optimally satisfy STRONG ONSET.

3.4.2. Factorial typology

The typology of the constraints in Tableaux (1-3) suggests three possible grammars that differ in the hierarchical position of the faithfulness constraint in relation to the fixed hierarchy of the two alignment constraints, as shown in Table (IX).

Table (IX) *Factorial typology of proposed ALIGN-L constraints*

	Constraint ranking	Resulting grammar
a.	**ALIGN-L(Stop,σ)** » **ALIGN-L([–closure],σ)** » **IDENT[Stop]**	Spirantization
b.	**ALIGN-L(Stop,σ)** » **IDENT[Stop]** » **ALIGN-L([–closure],σ)**	CodaCondition
c.	**IDENT[Stop]** » **ALIGN-L(Stop,σ)** » **ALIGN-L([–closure],σ)**	No alignment restriction on the distribution of stops

The "resulting grammars" in Table (IX) point towards familiar, well-documented grammar types, which the given rankings would naturally fit with, yet the rankings in (IX.a-c) do not attempt to adequately describe them, of course. For example, In a language that restricts coda consonants, the ranking in (IX.b) would, most probably, fit well, but it only exhibits a narrow prediction for stops. To effectively account for a Coda Condition grammar, other family members of the alignment constraints, that consider other classes of consonants (such as members of the hierarchy in (12) above) would have to be incorporated into the grammar. Likewise, the ranking in (IX.c) is far from an adequate description, yet for the opposite reason, since it is too broad. It should fit well with any language that tolerates stops in coda positions. The spirantization grammar in (IX.a) also lacks various specifications that would be necessary in order to limit the set of alternating stops and the triggering environments for the process of spirantization in various languages.

3.4.3. Accounting for the optimal C in VCV

Apart from its ability to account for natural spirantization processes, the proposed alignment scheme also contributes to a more general puzzle that arises from the reality of spirantization processes as "well-formedness" constraints. As mentioned before, it is commonly assumed that the unmarked onset consonant is a stop (at least since Jakobson 1941). At the same time, it is commonly assumed that the consonant in VCV environments syllabifies as an onset (although see Breen and Pensalfini's 1999 account of Arrente and Topintzi's 2008 account of moraic onsets for contradictory evidence). However, in grammars that promote spirantization the preferred onset consonant in VCV environments is a fricative, on grounds of well-formedness (i.e. due to phonetically/universally grounded principles, as opposed to language-specific faithfulness requirements).[24] The standard theory often uses construction-specific constraints to account for spirantization. Such cases, therefore, present us with two competing well-formedness (or markedness) constraints: One for the unmarked onset (by standardly assuming that a constraint such as $_{\sigma}$**[*STOP** is the lowest ranking variant of its kind), and another one for spirantization (such as ***V-STOP** (McCarthy 1996)). These different markedness constraints are superficially unrelated and they are not inherently ranked in respect to each other.

With the family of **ALIGN-L(C,σ)** constraints, it is possible to account for the unmarked onset syllable with a single mechanism that maintains a universally fixed hierarchy of well-formedness constraints, **ALIGN-L(Stop,σ)** » **ALIGN-L([–closure],σ)**. Cross-linguistically, the unmarked onset consonant is, indeed, a stop. However, the prediction for the preferred onset consonant is contingent upon structural configurations such as the initial position of Prosodic Phrases (Figure ii), or the second member of homorganic sequences (Figure iii), where the closure node of a stop does not mis-align. In other words, the set of alignment constraints predicts that the unmarked C in isolated CV syllables is a stop, but in VCV environments it is a fricative. This reality is often obscured by language-specific faithfulness constraints, in cases where stops and fricatives are not in complementary distribution and **IDENT** constraints retain the phonemic distinction between the two groups of obstruents at all the relevant environments.

24. See also Lleó and Rakow (2005).

3.5. Reviewing alternatives

Before moving on, it should make sense to consider alternative analyses to the experimental results, with other tools that are already available in the theory. For example, it should make sense to consider the family of **O**bligatory **C**ontour **P**rinciple (**OCP**, Leben 1973, 1978; McCarthy 1986) constraints, namely **OCP-MANNER**, which should ban the occurrence of two adjacent segments that share the same manner of articulation. This analysis will have to be further elaborated since no such effect was attested with two adjacent fricatives (*yaxpor* was not significantly better than *yaxfor*). This is possible if we maintain a fixed derived hierarchy where **OCP-STOP** is ranked higher than **OCP-FRICATIVE**, yet this plausible description does not explain much, as it does not lend a clue to let us understand why stops are more sensitive than fricatives to OCP effects. OCP, in that case, is only a descriptive tool, and as such it has less power than **ALIGN-L**.

Another familiar tool in the theory, that will yield similar results to **ALIGN-L** when accounting for the trends in group (I), is the set of sonority-based principles, namely: **S**onority **S**equencing **P**rinciple (**SSP**), **S**yllable **C**ontact **L**aw (**SCL**; Murray and Vennemann 1983, Vennemann 1988) and the **S**onority **D**ispersion **P**rinciple (**SDP**; Clements 1990, 1992).

According to the SSP, the optimal tautosyllabic consonant cluster (a complex onset or coda) retains a monotonous rise towards the peak/nucleus (i.e. optimal **onset** clusters steadily rise in sonority level), and a monotonous drop from the peak/nucleus (i.e. optimal **coda** clusters steadily drop in sonority level).

(15) SONORITY SEQUENCING PRINCIPLE[25]

a. In every syllable there is exactly one peak of sonority, contained in the nucleus.

b. Syllable margins exhibit a unidirectional sonority slope, rising toward the nucleus.

While SSP makes predictions within a syllable for tautosyllabic consonant clusters that map to complex onsets or codas, the capacity of the SCL concerns heterosyllabic sequences of consonants, at the contact between two adjacent syllables (16).

25. This formulation of the SSP is taken from Parker (2002:8).

(16) SYLLABLE CONTACT LAW[26]

A syllable contact A.B is the more preferred, the less the consonantal strength of the offset A and the greater the consonantal strength of the onset B.

Clements' (1990) **S**yllable **D**ispersion **P**rinciple (SDP) partly overlaps with both the SSP and SCL, while also introducing some novel advantages. The gist of it requires that onset positions will be **maximally** distant in sonority level from the following nucleus (i.e. it's better to have a consonant in onset position and the best onset is the least-sonorant obstruent), while coda positions should be **minimally** distant in sonority level from the preceding nucleus (i.e. it's better to have a the most sonorant possible segment in coda position and it's best to have no coda at all).

For the limited purposes of the experimental data I present here, the SCL and SDP yield similar predictions. In both cases a heterosyllabic sequence of consonants, C_1C_2, is preferred if the coda of the first syllable, C_1, is more sonorous than the following onset, C_2 (17.a). In the alternative scenario, a medial sequence could be a tautosyllabic onset cluster, which is restricted by the SSP to rising clusters, where C_1 should be less sonorous than C_2 (17.b).

(17) a. SCL preference: $C_1]_\sigma > {}_\sigma[C_2$
b. SSP preference: ${}_\sigma[C_1 < C_2$

In the following tableaux I use both SSP and SCL in order to capture the workings of common sonority-based restrictions on the CC sequences of the experimental data, whether they are syllabified as a heterosyllabic sequence or a tautosyllabic cluster. I use a dashed line to separate the SSP from the SCL since the possible ranking between the two complementary principles is irrelevant for the current study.

For simplicity's sake, I will not deal with other aspects of sonority-based principles, such as the possible requirement for a minimum sonority distance within tautosyllabic consonant clusters (Steriade 1982, Selkirk 1984). However, I acknowledge a somewhat gradient violation of sonority principles by postulating that a sonority reversal is more ill-formed

26. Vennemann (1988:40).

than a sonority plateau. While this does not seem to be controversial, it should be noted that according to Bat-El (1996), sonority plateaus in MH satisfy the SCL. While this may be true for a more complete grammar model of MH, where SCL violations in the form of sonority plateaus seem to freely occur, it should still be maintained that a fixed universal hierarchy of violations would posit sonority reversal above sonority plateau as a worse violation.

Tableau (4) demonstrate how sonority-based principles yield similar results to **Align-L (Stop,σ)** (compare with Table VII), given that we take fricatives to be more sonorous than stops (a common, yet not uncontroversial assumption, c.f. Clements 1990).

Tableau (4) *Sonority scale: **stop** < **fricative** with future conjugation of [tafas] 'will catch'*

/yitpos~yitfos/	*SSP reversal	*SSP plateau	*SCL reversal	*SCL plateau
a. [yi**t**.pos]				*!
b. [yi.**tp**os]		*!		
c. [yi**t**.fos]			*!	
d.☞[yi.**t**fos]				

One problem with the last analysis is that it is not fully consistent with the rest of the trends found in the experiment. For example, consider again the attested lack of clear preference between *yaxpor* and *yaxfor* (Group III). Tableau (5) wrongly predicts that candidate (5.a) should win (i.e. that *yaxpor* should be preferred), contrary to the experimental evidence.

Tableau (5) *Sonority scale: **stop** < **fricative** with future conjugation of [xafar] 'will dig'*

/yaxpor~yaxfor/	*SSP reversal	*SSP plateau	*SCL reversal	*SCL plateau
a.☛[yax.por]				
b. [ya.x**p**or]	*!			
c. [ya**x**.for]				*!
d. [ya.**x**for]		*!		

Different problems can be also detected with the strident-initial verbs in Group (II) when sonority-based principles are the active constraints. Since the relative sonority rank of stridents is a matter of much debate in the literature, to the extent that it is considered language-specific by many researchers, the following 5 Tableaux (Tableaux 6.i-v) consider different ranks in the hierarchy for stridents in relation to stop < fricative: (Tableau 6.i). strident < stop < fricative (stridents are the least sonorous); (Tableau 6.ii). stop < strident < fricative (stridents rank above stops and below fricatives); (Tableau 6.iii). stop < fricative < strident (stridents rank above stops and fricatives); (Tableau 6.iv). stop , strident < fricative (stridents pattern with stops); (Tableau 6.v). stop < strident , fricatives (stridents pattern with fricatives). All versions (Tableaux 6.i-v) use the future conjugation of *safar* 'counted', *yispor~yisfor* 'will count'.

Tableau (6.i) *Sonority hierarchy:* ***strident*** *<* ***stop*** *<* ***fricative***

/yisPor/	***SSP reversal**	***SSP plateau**	***SCL reversal**	***SCL plateau**
a. [yis.por]			*!	
b.☞[yi.s**p**or]				
c. [yi**s**.for]			*!	
d.☛[yi.**s**for]				

Tableau (6.ii) *Sonority hierarchy:* ***stop*** *<* ***strident*** *<* ***fricative***

/yisPor/	***SSP reversal**	***SSP plateau**	***SCL reversal**	***SCL plateau**
a.☞[yis.por]				
b. [yi.s**p**or]	*!			
c. [yi**s**.for]			*!	
d.☛[yi.**s**for]				

Tableau (6.iii) *Sonority hierarchy:* ***stop*** *<* ***fricative*** *<* ***strident***

/yisPor/	***SSP reversal**	***SSP plateau**	***SCL reversal**	***SCL plateau**
a.☞[yis.por]				
b. [yi.s**p**or]	*!			
c.☛[yi**s**.for]				
d. [yi.**s**for]	*!			

Tableau (6.iv) *Sonority hierarchy:* ***stop , strident < fricative***

/yisPor/	*SSP reversal	*SSP plateau	*SCL reversal	*SCL plateau
a. [yis.por]				*!
b. [yi.s**p**or]		*!		
c. [yi**s**.for]			*!	
d.☛[yi.**s**for]				

Tableau (6.v) *Sonority hierarchy:* ***stop < strident , fricative***

/yisPor/	*SSP reversal	*SSP plateau	*SCL reversal	*SCL plateau
a.☞[yis.por]				
b. [yi.s**p**or]	*!			
c. [yi**s**.for]				*!
d. [yi.**s**for]		*!		

Apparently, only the scale in (Tableau 6.v), in which stridents pattern with fricatives and both are more sonorous than stops, yields the correct result (preference for *yispor*). However, this seems to be a rather costly assumption since stridents in MH do not have the same distribution as non-strident fricatives. Namely, the fricatives [x] and [f] rarely (if ever) appear in the beginning of a word-initial complex onset with a following C_2 obstruent, while stridents often do, and with any type of C_2 manner that may follow it, excluding another strident (e.g. ***st**ima* 'sealing', ***sx**ava* 'duster', ***sm**ixa* 'blanket', **sl**ixa 'forgiveness', ***sy**ax* 'foal' etc.).[27] Clusters of this kind are sometimes known as *S-Clusters*, especially noted for their tendency to easily precede stops in complex onsets, thus exhibiting a sonority reversal in SSP terms (under standard assumption that strident fricatives are more sonorous than stops). In §4 I go back to the notion of sonority for further evaluations and discussion of its place in the grammar.

3.6. Modeling variation

First, it should be made clear that the phenomenon of stop~fricative variation in MH is not only inter-speaker but also intra-speaker, as the same speaker may exhibit inconsistent

27. There are a few examples where [x] precedes a stop (e.g. *xtav* 'hand-write').

productions of similar tokens. Furthermore, the variation at hand is subject to various pragmatic considerations, not just phonological ones (e.g. speakers generally tend more towards the normative forms in careful speech scenarios).

The phonological literature features some interesting attempts to model variation within the framework of Optimality Theory. Especially worth mentioning are Anttila & Cho (1998), who suggest a model of partial constraint ranking where it is possible to model invariant and variable phenomena and derive their statistical predictions, and Boersma & Hayes (2001), who suggest a continuous scale of constraint strictness and a stochastic grammar which can produce variable outputs when some constraint rankings are close to each other. Although these proposals are different in essence, they share the idea that the underlying input is fixed while variation is accounted for by virtue of more "elastic" and intricate constraint ranking than the standard theory assumes.

The position I take on variation in the stop-fricative alternation of MH is different (see §3.6.2 below for a brief discussion). I assume that MH speakers have a fixed grammar (for that matter), which resembles the one proposed earlier for English (Table IX.c, repeated below in 18), since MH speakers generally do not violate faithfulness requirements on stops and fricatives in non-alternating positions (including post-consonantal positions).

(18) IDENT[Stop] » **ALIGN-L(Stop,σ)** » **ALIGN-L([–closure],σ)**.

To account for the observed variation phenomenon in MH I employ the notion of *Underspecification*, much in the flavor of Inkelas' (1995) *Archiphonemic Underspecification*. The terms *Archiphoneme* and *Underspecification* are already loaded, and Inkelas, indeed, refers to the *archiphoneme* of the Prague school (Jakobson 1929, Trubetzkoy 1929, 1936, Martinet 1936) and to the classic views of *underspecification* within a feature-based theory (Clements 1988; Steriade 1987; Kiparsky 1982; Archangeli 1984; Pulleyblank 1986), where only contrastive or unpredictable features are assumed to be part of the underlying representation (UR). However, her notion of the archiphoneme and her model of underspecification differ from those classic concepts in some crucial manners. Archiphonemic Underspecification is presented within the framework of Optimality Theory where it is restricted by a process of *Lexicon Optimization* (Prince and Smolensky 1993), which yields underspecified input material only in cases that exhibit alternations. An underspecified UR is chosen when surface evidence for a possible UR is indeterminate. In her restatement of this process, Inkelas describes *Lexicon Optimization* in cases that exhibit alternation (Inkelas 1995:6-7) (19).

(19) Alternation-sensitive restatement of *Lexicon Optimization*

> "Given a grammar G and a set S = {S_1, S_2, ... S_i} of surface phonetic forms for a morpheme M, suppose that there is a set of inputs I = {I_1, I_2, ... I_j}, each of whose members has a set of surface realizations equivalent to S. There is some $I_i \in I$ such that the mapping between Ii and the members of S is the most harmonic with respect to G, i.e. incurs the fewest marks for the highest ranked constraints. The learner should choose I_i as the underlying representation for M."

3.6.1. Underspecification

In what follows I build on Inkelas' alternation-sensitive restatement of *Lexicon Optimization*, by extending it to capture the most harmonic UR in variation cases, where a given alternation is unstable. In Tables (X)-(XI) there are two possible surface representations, (a)-(b), for any one of the three possible UR's, (i)-(iii). The potential UR features either a pre-specified fricative ([f]) or stop ([p]), or an underspecified archiphoneme ([P]), which is a labial obstruent, not fully specified for manner of articulation. A process of Lexicon Optimization is expected to drive speakers to deduce the most harmonic UR, given the attested surface representations and the grammar (formally, ranked constraints) on the one hand, and the potential UR's on the other.

In the following 2 Lexicon Optimization tables (often termed *tableau of tableaux*) I collapse the faithfulness requirements for both stops and fricatives under one constraint, **Ident[Obs-Man]**, which protects the particular manner of articulation of obstruents (either fricatives or stops). This constraint outranks **Align-L(Stop,σ)** in the fixed grammar of MH.

Table (X) *Lexicon Optimization with a varying stop-fricative alternation*

Lexicon Optimization	UR	SR	IDENT[Obs-Man]	ALIGN-L(Stop,σ)
i.	/yit**f**os/	a. [yit**f**os]		
		b. [yit**p**os]	*!	*
ii.	/yit**p**os/	a. [yit**f**os]	*!	
		b. [yit**p**os]		*!
iii. ☞	/yit**P**os/	a. [yit**f**os]		
		b. [yit**p**os]		*!

In Table (X), both (a)-type and (b)-type surface representations (SR's) should be allowed to surface, so the pre-specified UR's in (X.i) and (X.ii) will always violate the highly ranked IDENT in one of their two potential SR's. The underspecified labial obstruent in (X.iii), however, will always vacuously satisfy this faithfulness requirement, yielding a better UR.

Table (XI) *Lexicon Optimization with a stable alternating stop-fricative*

Lexicon Optimization	UR	SR	IDENT[Obs-Man]	ALIGN-L(Stop,σ)
i. ☞	/ta**f**as/	a. [ta**f**as]		
		b. *[ta**p**as]	*!	
ii.	/ta**p**as/	a. [ta**f**as]	*!	
		b. *[ta**p**as]		
iii.	/ta**P**as/	a. [ta**f**as]		
		b. *[ta**p**as]		

In Table (XI), only the (a)-type SR is licit, while the (b)-type SR does not generally occur. In this case, the highly ranked faithfulness constraint will successfully ban illicit (b)-type SR when it is not underlyingly similar to the UR as in (XI.i). The underspecified UR in (XI.iii) will not be able to choose the correct SR with this grammar.

While some verbs (such as the 9 target verbs in the experiment) are yet to assume a fixed surface output form, other comparable verbs seem to surface without such attested variation. For example, consider the pa'al verbs *naxax* 'participate' and *maxar* 'sell', which feature an alternating velar obstruent ([x~k]) in C_2. In the future conjugations, these verbs are expected to behave similarly since they both feature a nasal consonant ([n]/[m]) in their C_1 position.

However, the findings from the preliminary pilot experiment show, overwhelmingly, that these verbs exhibit no variation, yet in two opposite directions: The 22 participants in the pilot experiment produced the future forms *yim**k**or* 'will sell' (but not *yimxor*) and *yin**x**ax* 'will participate' (but not *yinkax*).

(20) a. [yim**k**or] / *[~~yimxor~~] (Nasal-Stop » Nasal-Fricative)

b. *[~~yinkax~~] / [yin**x**ax] (Nasal-Fricative » Nasal-Stop)

The data in (20.a-b) may initially seem to lack an underlying phonological generalization that would point at a possible explanation for the two extreme and opposite trends. It is possible to assume that while (20.a) may reflect a preferred trend for post nasal stops, (20.b) may reflect an identity requirement between C_2 and C_3 in MH (see Bat-El's 2006 account on reduplication). However, these plausible explanations should be expected to appear as trends, not as a complete ban on one specific form (indeed, as a native speaker of MH, I acknowledge that the banned forms *[yinkax] and *[yimxor] do seem to be unattested).

Such cases that exhibit no variation give rise to claims based on differences between underlying input forms due to processes of lexicaliztation (mediated by Lexicon Optimization processes, as described above). According to this line of thought, the opaque phonological nature of the stop-fricative alternation in MH should lead speakers to assume an underspecified UR in cases where unstable variation occurs regularly. When no variation occurs, however, a fully specified UR should be assumed.

Tableaux (7-8) demonstrate how this works under the assumption that non-varying SR's are derived by fully specified UR's. In these tableaux, no variation is attested in the surface forms, and, likewise, the UR is fully specified. The winning candidate is selected by the highly ranked — and active — faithfulness constraint.

Tableau (7) *Fully-specified input for [yim**k**or] 'will sell'*

/yi**mk**or/	**Ident** [Obs-Man]	**Align-L** (Stop,σ)
a.☞[yi**mk**or]		
d. [yi**mx**or]	*!	

Tableau (8) *Fully-specified input for [yinxax] 'will participate'*

/yi**nx**ax/	**IDENT [Obs-Man]**	**ALIGN-L (Stop,σ)**
b. [yi**nk**ax]	*!	
c.☞[yi**nx**ax]		

Unlike the examples above, Tableau (9) demonstrates a case where the SR varies somewhat unpredictably [yitpos~yitfos], yet with attested preferences towards one form [yitfos]. This is achieved by the underspecification of the particular manner of articulation of the spirantizable obstruent in C_2, which renders the faithfulness constraint as vacuous. The selection by a lowly ranked, and mostly inactive, ALIGN-L constraint, is "weaker" than the previous selection of winning candidates by IDENT.

Tableau (9) *Underspecified input for [yit**f**os»yit**p**os] 'will catch'*

/yit**P**os/	**IDENT [Obs-Man]**	**ALIGN-L (Stop,σ)**
a. [yit.pos]		*!
b. [yi.tpos]		*!
c. [yit.fos]		*!
d.☞[yi.tfos]		

Modeling variation with underspecified UR's seems advantageous in this case since it allows pragmatic (or even meta-linguistic) considerations to interfere with the outcome. In careful speech scenarios, for example, even underspecified inputs may assume a fully-specified form. To illustrate this, we can think of a speaker that will make an effort to speak "correctly", thus forcing the normative input form in some cases, rendering the UR as fully specified (Tableau 10).[28]

28. In the following tableaux I added the markedness constraint *COMPLEX, which should rank low in MH, as the language generally tolerates complex clusters. In any case, it must rank lower than Align-L(Stop,σ) to yield the correct winning candidates (e.g. *yi.tfos*).

Tableau (10) *Forced specification (careful speech) input for [yit**p**os] 'will catch'*

/yi**tp**os/	IDENT [Obs-Man]	ALIGN-L (Stop,σ)	*COMPLEX
a.☞[yi**t**.**p**os]		*	
b. [yi.**tp**os]		*	*!
c. [yi**t**.fos]	*!	*	
d. [yi.**t**fos]	*!		*

Another advantage of this model of variation lies in its ability to predict directions of change given the frequency of occurrences that are governed by emerging low-level well-formedness constraints, and the resulting UR, which is governed by Lexicon Optimization processes. In other words, given that the preference in cases like [yitpos~yitfos] is towards the less marked form [yitfos], the prediction for a final state will assume that future generations of MH speakers may eventually regard this preferred form as the fixed form, thus arriving at a fully specified non-normative UR (Tableau 11).

Tableau (11) *Fully-specified (final state) input for [yit**f**os] 'will catch'*

/yi**t**fos/	IDENT [Obs-Man]	ALIGN-L (Stop,σ)	*COMPLEX
a. [yi**t**.**p**os]	*!	*	
b. [yi.**tp**os]	*!	*	*
c. [yi**t**.fos]		*!	
d.☞[yi.**t**fos]			*

3.6.2. Variation: A brief discussion

While I chose to formally model the variation at hand with underspecified inputs, I do not reject formal models of the kind that I mention in §3.6 (Anttila & Cho 1998, Boersma & Hayes 2001), which assume different rankings rather than different types of inputs. However, I believe that these generally different models should fit different kinds of variation (within a particular grammar). For the sake of the argument, I will make a distinction between variation triggered by different *modes of speech* (e.g. rapid vs. slow speech) and variation that is lexically conditioned, such as the variation arising from the data in this paper.

Lexically conditioned variation can be modeled with underspecified inputs, or, alternatively, with fully specified inputs that must bear a special mark in order to trigger reranking. Thus, since underspecification requires fewer theoretical entities in order to achieve the same complex interaction between some input(s) in the lexicon and some faithfulness constraint(s) in the grammar, it is preferred in this scenario by Occam's Razor. This ceases to be the case when variation is triggered by *modes of speech*, since the reranking of constraints is not governed by lexical entries and there are no redundant entities that would disfavor a reranking model.

3.7. Notes on syllabification

As it turns out, the preference for C_2 fricatives after C_1 stops entails a preferred syllabification of the medial sequence as an onset cluster. This seems to be the prediction when using **ALIGN-L(Stop,σ)** (Table VII), as well as sonority based principles (Tableau 4). In both cases the winning candidate is of the form *yi.**tf**os*, rather than *yi**t.f**os*. However, this division into syllables is not the commonly assumed one (when presented with this meta-linguistic question, most MH speakers would claim that a CVC.CVC division is the correct one), and there is no straight-forward way to independently verify that. The following sub-sections will present an attempt to verify syllabification in MH, based on independent phonetic cues.

3.7.1. Vowel length experiment

According to Maymon (2001), open syllables have longer vowels than closed syllables in MH, but only in stressed syllables. To verify these effects, the stimuli of the first experiment included 2 filler sentences which were targeted for measurements of vowel length in closed vs. open syllables (both stressed). The target syllables were inserted in a list of girls' names such that the two target words were adjacent in the middle of the list, each time in the opposite direction in respect to each other (21).

(21) a. רינה, **תיקווה, תימנע** ועדינה נמצאות בערבה
rina ˈ***tikva*** ˈ***timna*** *ve-adina nimcaot ba-arava*
'Rina, Tikva, Timna and Adina are in the Arava'

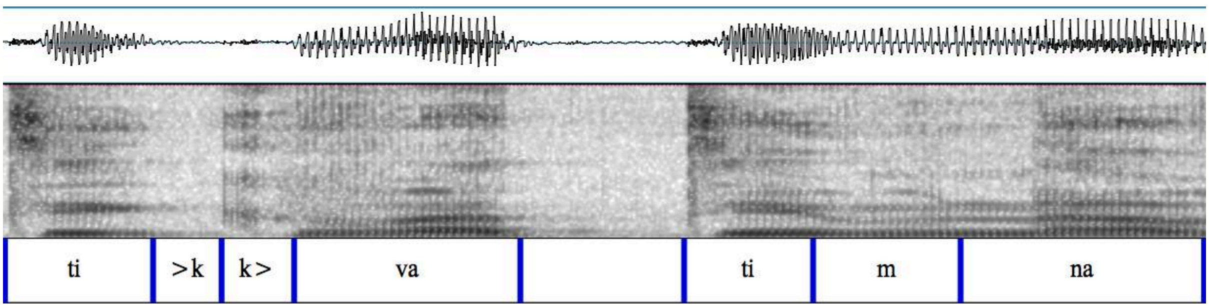
b. לרינה, **תימנע, תיקווה** ועדינה יש אותו רואה-חשבון
le-rina ˈ***timna*** ˈ***tikva*** *ve-adina yeš oto roe xešbonm*
'Rina, Timna, Tikva and Adina have the same accountant'

The medial stop-initial sequence in ˈ*tikva* is assumed here to preferably syllabify as a complex onset, thus the initial CV portion (*ti*) is predicted to behave like an open syllable (ˈ***ti***.*kva*). The medial nasal-initial sequence in ˈ*timna* is (commonly) assumed to syllabify across syllables, thus the initial CVC portion (*tim*) is predicted to behave like a closed syllable (ˈ***tim***.*na*). Since the first syllable in both instances is stressed, differences in syllabification are expected to be reflected in vowel length.

3.7.2. Vowel length results

The measurements take the *ti-* portion of each target word in each pair and compare lengths per pair.[29] Lengths were measured in productions that maintained a steady "list rhythm" for the two medial target names (16 valid productions of the ˈ*tikva* ˈ*timna* variant and 11 valid productions of the opposite ˈ*timna* ˈ*tikva* variant).

Figure (vii) *Example screenshot of the PRAAT analysis window*



29. Measurements start at the release of [t], until the end of an audible vowel (before the silence that precedes the release of [k] in *tikva*). In the case of *timna*, until characteristic formants of [i] switch to those characteristic of [m] (mainly, lower F1). Measurements were taken using PRAAT software (Figure vii).

Table (XII) *Differences in [ti-] lengths*

	Longer *ti-* in ***tikva***		Longer *ti-* in ***timna***		
	Occurrences	Longer mean	Occurrences	Longer mean	Significant differences in *ti-* length
ˈ***timna*** ˈ***tikva***	**63.6%**	**1.18%**	36.4%	1.03%	**yes**: $t(10) = -2.300$, $p = .044$
ˈ***tikva*** ˈ***timna***	**56.25%**	**1.15%**	43.75%	1.13%	no: $t(15) = -.689$, $p = .501$

Values were significantly higher for *ti-* in *tikva*, but only in the ˈ*timna* ˈ*tikva* pair (p = .044). Differences in length were highly insignificant (p = .501) in the ˈ*tikva* ˈ*timna* pair, although *ti-* in *tikva* was overall longer in that pair as well. Indeed, [ti] seems to be generally longer in [ˈ**ti**kva] than in [ˈ**ti**mna]. However, the differences were small and somewhat inconsistent, with attested noise that should be attributed to the order of the stimuli. Therefore, it should be taken with caution.

3.7.3. C-Center effect

It is of interest to point at another promising experimental venue that may independently verify syllabification, based on the coordination of articulatory gestures. Research in Articulatory Phonology suggests evidence for the claim that the abstract organization of speech sounds into syllables is reflected in temporal patterns of speech production (Krakow 1999, Goldstein et al. 2007, Shaw et al. 2009). According to this methodology, in complex onsets the timing of the consonants in the cluster is adjusted in relation to a following articulatory anchor when compared to simple onsets. This is known as the C-center effect or center stability (Browman and Goldstein 1988, Hermes et al. 2008, Shaw et al. 2009, Marin and Pouplier 2010), which is based on the assumption that the distance from the center of the onset to the following vowel remains steady in examples such as ***lay*** vs. ***play***. This adjustment can be measured as the interval of the mean of consonantal targets relative to a following target in the word. However, such measures require specific articulatory machinery (electromagnetic articulography) that is, unfortunately, not within reach for the purpose of the current paper. However, this methodology seems like a promising independent measure for syllabification in MH, and it should be able to strengthen or weaken the proposals made here thus far.

4. What's *Sonority* got to do with it?

The notion of sonority was mentioned in the previous analysis, yet it was not found to have much explanatory power for the attested phonotactic trends (§3.5). Sonority-based principles are often considered when dealing with the phonotactics of consonantal sequences, yet sonority effects are often not very predictable and coherent when dealing with sequences of obstruents (the problems of analyzing S-Clusters is among the most famous of this kind, see Goad 2011 for an extensive overview). The problems with sonority-based principles run deeper than that, mainly due to the fact that sonority is a notion that does not rely on an agreed upon phonetic correlate, and the details of its hierarchy are a source of debate even after more than 100 years of linguistic research, at least since Sievers (1881) and Jespersen (1904) (see Parker 2002 for an exhaustive review of the sonority debate).

The position I take here is that the notion of sonority gained more explanatory power than it actually should. Given that one prominent aspect of language is redundancy of (phonological as well as syntactic/semantic/pragmatic) information, it should come as no surprise that some good linguistic generalizations seem to cover more phenomena than they should, by virtue of their vague definition, and due to the empirical overlap of seemingly related phenomena. To that extent, I argue that the reality of **Align-L(Stop,σ)** constraints are often obscured by an over-blown notion of sonority.

In the following sub-sections, I briefly sketch a proposal that attempts to redefine sonority such that a slimmer and weaker — yet more coherent — entity will eventually unfold. Although this theoretic endeavor does not seem to be directly related to this paper, it is, in fact, a major part of the underlying motivation behind it. A weaker version of sonority necessitates that alternative universal phonotactic principles will be incorporated into the general theory to properly cover areas of the grammar that were previously covered by virtue of vaguely defined sonority. The attempt to bring **Align-L(Stop,σ)** constraints to the fore is the other side of the coin that would eventually reduce the empirical coverage of sonority-based principles.

4.1. Nucleus attraction

The relative sonority level of speech sounds represents their ability to fill, or "attract", the nucleus position of a syllable, such that in a given sequence of sounds, the more sonorous ones will be more capable of attracting nuclei. The question that arises, then, is what is it that attracts nuclei, or, in other words, what makes one segment more sonorous than the other?

There are many proposals that attempt to answer this question, from theories that assume no phonetic correlation for sonority as a "pure" theoretical construct of phonology, to theories that assume that phonetic correlates do exist. The latter, more commonly accepted assumption, is another source of debate as some researchers correlate sonority with articulatory features (namely the relative *airflow* in the production of speech sounds) while others correlate it with perceptual features (namely the relative loudness or *audibility* of speech sounds in the acoustic domain). While a substantial overlap between relative *airflow* and relative *audibility* is expected among the class of *sonorant* sounds (nasals, liquids, glides and vowels), discrepancies between *airflow* and *audibility* should be expected, and are widely attested, in the patterning of obstruents on the lower edge of the sonority scale. This discrepancy is especially familiar when dealing with the problematic status of stridents, that are articulatorily fricatives (i.e. very low in terms of relative airflow), yet they are acoustically characterized by a disharmonic concentration of energy at the higher frequency spectrums (i.e. very high in terms of relative audibility).

In the next sub-section I present a strictly perceptual account of sonority that is coherent in its correlation of sonority with the cognitive sensation of pitch (or 'tone').

4.2. Harmony, disharmony and duration

Clements (2009) suggests the term *Resonance* in relation to sonority:

> *"Resonant sounds are optimal bearers of the prosodic properties that are typically associated with syllables. Vowels, as the highest-sonority sounds, are ideally suited to the function of anchoring the distinctive F0 variations found in tone, pitch-accent and intonation systems"* (p. 170); *"we may consider voicing [...] as a precondition for the perception of resonance in speech sounds"* (p. 169).

I adopt Clements' (2009) definition of *Resonance* as the ***Harmonic*** component of speech sounds, which is achieved by voicing. Perceptually speaking, pitch (or tone) is a cognitive interpretation of a periodic sound with a distinct harmonic series of frequencies (formants). More audible harmonic component in speech sounds contributes to greater sonority (e.g. vowels are more sonorous than liquids, voiced obstruents are more sonorous than voiceless obstruents, etc.).

Harmony is not the only component that contributes to the sensation of pitch, though. At least two more independent components of speech sounds should be invoked. One is ***Disharmony***, which is acoustically characterized by non-periodic (non-harmonic) series of frequencies, achieved by certain articulatory contact gestures (namely the turbulent airstream caused by frication). More audible disharmonic component contributes to lesser sonority as it interferes with the sensation of pitch (e.g. voiced fricatives are less sonorous than (voiced) liquids, and strident fricatives are less sonorous than non-strident fricatives).

The third, and last, component is ***Duration***. In order to bear tone, sounds need some audible duration, which stops lack, as they are only audible at their release (as well as in the cues of shifting formants at the transition from preceding segments). Therefore, stops are highly non-sonorous because they lack an audible duration to promote the sensation of pitch.

Table (XIII) *Summary of nucleus attraction components*

Speech sound	**Harmonic Component**	**Disharmonic Component**	**Duration**
(Low and Mid) **Vowels**	high audibility	no interruption	yes
Semi-Vowels (Glides and High Vowels)	mid audibility	no interruption	yes
Liquids, Nasals	low audibility	no interruption	yes
Non-strident Fricatives (voiced)	low audibility	low interruption	yes
Stridents (voiced)	low audibility	high interruption	yes
Stops (voiced)	low audibility	low interruption	no
Non-strident Fricatives (voiceless)	no audibility	low interruption	yes
Stridents (voiceless)	no audibility	high interruption	yes
Stops (voiceless)	no audibility	low interruption	no

Table (XIII) illustrates these 3 independent components of pitch perception in speech. It should be assumed that much in the way that the sensation of stress is a combination of (at least) 3 independent elements (pitch, loudness and duration) that conspire together to various language-specific degrees, the sensation of pitch is built of (at least) 3 independent acoustic domains, which are not necessarily equally important. In other words, the sensation of stress is not equally quantified in all stress languages, in respect to the 3 acoustic domains (e.g. while stress in American English may be more attuned to pitch (Hayes 1995, Lieberman 1960), in MH it seems that duration is the more salient aspect of stress (Becker 2003)). The sensation of pitch in speech sounds, in much the same way, may differ in the salience that different languages may assign to its different components. Therefore, while the parameters in Table (XIII) should remain fixed, languages may derive slightly different sonority scales out of it, mainly in relation to the relative weight they assign to the disharmonic component.

4.3. Advantages

Viewed this way, *audibility*, is no more a vague concept relating to the evasive notion of "perceived loudness", as it now relates more specifically to the audibility of the harmonic (voiced) component of speech sounds, as well as the (in)audibility of the disharmonic component. This version of sonority is a coherent perceptual entity, based on 3 distinctive features (harmony, disharmony and duration), with an inherent ability to account for frication and stridency, as well as voicing and duration.

With this view of sonority it is no longer the case that *S-clusters* (where [s] appears in margins of clusters; preceding stops in onset clusters, and following stops in coda clusters) exhibit sonority reversals. S-clusters simply do not attract the nucleus so they do not necessarily violate sonority-based principles. The elimination of the idea that S-clusters often violate sonority, paves the way for other phonotactically-driven universals to explain their attested distribution in languages (more suggestions for the direction to take on S-Cluster cases are suggested in the following sub-section, §4.4.).

What should remain similar to common sonority-based proposals is the general flavor of preferred sonority profiles: A sequence of sounds in the speech stream will be optimally parsed into units (syllables) such that there is a monotonous/coherent attraction of the nucleus in any given unit.

4.4. Stridents revisited

One reasonable path of explanation for the attested trend with Group (II) (the preference towards a stop rather than a fricative when following a strident), may come from relative perceptual cue robustness (Wright 2004). The transition from stridents to stops (e.g. from [s] to [p]) features more robust cues for proper segmental categorization than those found in the transition from stridents to fricatives (e.g. from [s] to [f]). In other words, strident-initial sequences may be preferred with a following stop rather than a following fricative, on grounds of perceptual cue robustness, regardless of syllabic position. Of course, a fuller account of the appearance and distribution of stridents, cross-linguistically, is also contingent upon other phonotactically-driven principles, such as the hierarchy of preferred syllable types, the stop-alignment scheme and sonority-based constraints.

Note, however, that while the suggested pitch-based definition for sonority eliminates the theoretical "misbehavior" of stridents in S-clusters, this problem resurfaces in respect to the new alignment proposal, since stops that follow stridents in onset clusters are supposedly mis-aligned. Thus, although one desirable outcome of the pitch-based sonority program would have been to avoid the use of extra-syllabic tools that force stridents out of the syllabic tier with notions such as the *appendix* (Blevins 1995, Chierchia 1986, Goldsmith 1990, Green 2003, Pierrehumbert 1994, Rialland 1994, Steriade 1982 and Vaux 2004, to name a few prominent examples), extra-syllabic tools may still be needed to account for the distribution of stridents in marginal positions of sequences.

Interestingly, since languages with Coda Condition and spirantization processes, as in Grammars (IX.a) and (IX.b) above, are not expected to include S-clusters in their inventory, the fact that such S-clusters do exist in other languages (Grammar IX.c), where faithfulness outranks the ALIGN-L constraints, can be understood as a straight-forward outcome of the demoted nature of ALIGN-L in these languages (otherwise it would ban such mis-aligned clusters).

At the same time, there is evidence from Italian, based on experimental articulatory data, that corroborate the extra-syllabic status that stridents may assume. Using C-center effect tests (see §3.7.3) Hermes et al. (2008) found that word-initial S-Clusters in Italian (e.g. [spl], [sp]) behave differently than other clusters in the language. Italian S-Clusters maintain the same center stability in articulation, when compared against similar strident-less cases (e.g. [pl], [p]). This means that stridents may be outside the unit of articulation, which we standardly associate with the syllable. This articulatory-based notion of the syllable is the same one that is also relevant to the observations regarding alignment in this paper. Therefore, it may be possible that stops following stridents in onset clusters do not necessarily violate **ALIGN-L(Stop,σ)** due to the alleged extra-syllabic status of the preceding strident.

4.5. Prediction for true sonority reversals

The final note on sonority is a brief prediction for other challenging clusters for sonority-based descriptions, namely languages with sonorant-stop initial clusters like Russian, where word-initial [rtV] and [lbV] clusters are attested. A pitch-based notion of sonority will essentially predict that sonorants which appear in the beginning of complex clusters will not appear as syllabic consonants in other positions because this will entail a paradox for the concept of nucleus attraction. For example, if [l] can open a complex onset in ways that constitute a sonority reversal (e.g. [lbV]), we should assume that in that language it will minimally attract nuclei and is, therefore, not expected to fill the nucleus position as a syllabic consonant.

5. Conclusions

This work assumes that there is a phonetic basis for synchronic phonological phenomena, yet it does not necessarily reject a lexicalist approach, which assumes that speakers derive their phonotactic knowledge by generalizing over their lexicon (e.g. Frisch & Zawaydeh 2001, Hay et al. 2003). Daland et al. (2011) present some compelling evidence for the possibility of deriving sonority-based principles from the lexicon, even in languages that are considered to be CV languages like Korean and Mandarin. They further argue that in order to cover the fact that sonority-based principles are evidently universal, yet not present in the mental grammar of speakers (according to lexicalist approaches), a theory like Blevins' (2004) Evolutionary Phonology may suffice, since the universality of phonetically-based principles is part of the diachronic grammar. However, Daland et al. (2011:231) conclude that it is their belief that principles such as the SSP are derived "from a combination of lexical and universal (non-lexical) knowledge". This conclusion seems acceptable from the point-of-view of the current study as well, as it readily acknowledges the fact that the phonetically-based generalizations proposed here do not tell the whole story of spirantization-related variation in MH.

In line with this assumption, the working hypothesis behind the analyses I presented, attempts to make clear the distinctions between articulatory-based and perceptually-based phenomena. Using a familiar case of variation in MH, this work starts off with an experimental methodology that reveals subtle, yet systematic, phonotactic trends in MH. These trends are assumed, in line with TETU, to reflect low ranking well-formedness constraints in the grammar of MH. I propose an analysis for one of the two observed trends, where I utilize the *Alignment* constraints scheme to account for attested phonotactic preferences. My proposal is phonetically motivated, with good empirical coverage, and it is not just theoretically plausible, it also seems advantageous in predicting the optimal onset consonant cross-linguistically.

The last part of this paper was devoted to a brief presentation of a program to redefine sonority. I sketch the basic concepts behind my proposal, its relevance to the alignment scheme that I presented in the first part, and some immediate benefits in this program's ability to solve some of the long-standing debates about sonority in the phonological literature.

Eventually, this work is a small step in an ongoing effort to redefine sonority in a coherent way as a perceptual construct related exclusively to the perception of pitch, perhaps the most important cognitive primitive in the human auditory system, and one which also lies at the core of our primal auditory art form — music.

6. References

Abrahamsson, Niclas. 2003. Development and recoverability of L2 codas. *Studies in second language acquisition* 25(3): 313-349.

Abramson, Arthur S. and Kalaya Tingsabadh. 1999. Thai final stops: cross-language perception. *Phonetica* 56(3-4): 111-122.

Adam, Galit. 2002. *From variable* to *optimal grammar: Evidence from language acquisition and language change*. PhD dissertation, Tel-Aviv University.

Anttila, Arto and Young-mee Yu Cho. 1998. Variation and change in optimality theory. *Lingua* 104: 31-56.

Archangeli, D. I984. *Underspecification in Yawelmani phonology and morphology*. PhD dissertation, MIT. Published I988, New York: Garland.

Baković, Eric. 1995. Strong onsets and Spanish fortition. In *Proceedings of SCIL 6*. Cambridge, MA: MITWPL.

Barkaï, Malachi. 1974. On duration and spirantization in Biblical Hebrew. *Linguistic Inquiry*, 456-459.

Barkai, Malachi and Julia Horvath. 1978. Voicing assimilation and the sonority hierarchy: evidence from Russian, Hebrew, and Hungarian. *Linguistics* 212: 77-88.

Bat-El, Outi. 1994. Stem modification and cluster transfer in modern Hebrew. *Natural Language and Linguistic Theory* 12: 571-596.

Bat-El, Outi. 1996. Selecting the best of the worst: the grammar of Hebrew blends. *Phonology* 13: 283-328.

Bat-El, Outi. 2001. In Search of the Roots of the C-Root: The Essence of Semitic Morphology. *Handout of talk presented at the Workshop on Root and Template Morphology*, University of Southern California.

Bat-El, Outi. 2002. True Truncation in Colloquial Hebrew Imperatives. *Language* 78:651-683.

Bat-El, Outi. 2006. Consonant identity and consonant copy: the segmental and prosodic structure of Hebrew reduplication. *Linguistic Inquiry* 37(2): 179-210.

Bat-El, Outi. 2011. Semitic templates. In *Blackwell companion to phonology*: 2586-2608.

Becker, Michael. 2003. Hebrew stress: Can't you hear those trochees? In Elsi Kaiser and Sudha Arunachalam (eds.), University of Pennsylvania Working Papers in Linguistics 9.1: *Proceedings of the 26th Annual Penn Linguistics Colloquium*: 45-48.

Berman, Ruth Aronson. 1978. *Modern Hebrew Structure*. Tel Aviv: Universities Publishing Projects.

Blevins, Juliette. 1995. The syllable in phonological theory. In *The Handbook of Phonological Theory*, John Goldsmith (ed.), 206-244. Oxford: Blackwell.

Blevins, Juliette. 2004. *Evolutionary phonology: The emergence of sound patterns*. Cambridge University Press

Boersma, Paul and Bruce Hayes. 2001. Empirical tests of the gradual learning algorithm. *Linguistic Inquiry* 32(1): 45-86.

Bolozky, Shmuel. 1978. Some aspects of Modern Hebrew phonology. Chapter II in R. Aronson Berman, *Modern Hebrew Structure*. Tel Aviv: Universities Publishing Projects: 11-67.

Bolozky, Shmuel. 1978. Some aspects of Modern Hebrew phonology. In *Modern Hebrew Structure*, 11-67.

Breen, Gavan and Rob Pensalfini. 1999. Arrernte: A language with no syllable onsets. *Linguistic Inquiry* 30(1): 1-25.

Browman, Catherine P. and Louis Goldstein. 1988. Some notes on syllable structure in Articulatory Phonology. *Phonetica* 45: 140-155.

Chierchia, Gennaro. 1986. Length, syllabification and the phonological cycle in Italian. *Journal of Italian Linguistics* 8: 5-33.

Clements, George N. 1988. Toward a substantive theory of feature specification. In *Proceedings of North East Linguistic Society* 18: 79-93.

Clements, George N. 1990. The role of the sonority cycle in core syllabification. In *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech*, John Kingston & Mary Beckman (eds.), 283-333. Cambridge: Cambridge University Press.

Clements, George N. 1992. The sonority cycle and syllable organization. *Phonologica 1988*: 63-76.

Clements, George N. 2009. Does Sonority Have a Phonetic Basis? *Contemporary views on architecture and representations in phonology* 48: 165-175.

Daland, Robert, Bruce Hayes, James White, Marc Garellek, Andrea Davis, and Ingrid Norrmann. 2011. Explaining sonority projection effects. *Phonology* 28(2): 197-234.

Dresher, Bezalel Elan. 1994. The prosodic basis of the Tiberian Hebrew system of accents. *Language*: 1-52.

Frisch, Stefan A. and Bushra Adnan Zawaydeh. 2001. The psychological reality of OCP-place in Arabic. *Language* 77: 91-106.

Goad, Heather. 2011. The representation of sC clusters. In M. van Oostendorp, C. Ewen, E. Hume & K. Rice (eds.) *The Blackwell companion to phonology* 2: 898-923.

Goad, Heather, and Kathleen Brannen. 2003. Phonetic evidence for phonological structure in syllabification. *Amsterdam studies in the theory and history of linguistic science series* 4: 3-30.

Goldsmith, J. 1990. *Autosegmental Phonology*. New York: Garland Press.

Goldstein, Louis, Ioana Chitoran and Elisabeth Selkirk. 2007. Syllable structure as coupled oscillator modes: Evidence from Georgian vs. Tashlhiyt Berber. *Proceedings of the XVIth International Congress of Phonetic Sciences*, Saarbrücken, Germany, 241-244.

Green, Antony. 2003. Extrasyllabic consonants and Onset Well-formedness. In C. Féry & R. van de Vijver (eds.), *The Syllable in Optimality Theory*, 238-253. Cambridge: Cambridge University Press.

Hay, Jennifer, Janet B. Pierrehumbert and Mary E. Beckman. 2003. Speech perception, well-formedness and the statistics of the lexicon. In John Local, Richard Ogden & Rosalind Temple (eds.) *Phonetic interpretation: papers in laboratory phonology* VI. Cambridge: Cambridge University Press: 58-74.

Hayes, Bruce. 1986. Inalterability in CV phonology. *Language*, 62(2): 321-351.

Hayes, Bruce. 1995. *Metrical stress theory: Principles and case studies*. University of Chicago Press.

Hermes, Anne, Martine Grice, Doris Mücke and Henrik Niemann. 2008. Articulatory indicators of syllable affiliation in word initial consonant clusters in Italian. In: Sock R, Fuchs S, Laprie Y (eds.) *Proceedings of the 8th International Seminar on Speech Production*, Strasbourg, France, 433-436.

Idsardi, William J. 1998. Tiberian Hebrew spirantization and phonological derivations. *Linguistic Inquiry* 29: 37-73.

Inkelas, Sharon. 1995. The consequences of optimization for underspecification. *Proceedings-NELS* Vol. 25. University Of Massachusetts.

Itô, Junko. 1986. *Syllable Theory in Prosodic Phonology*. PhD thesis, University of Massachusetts, Amherst.

Itô, Junko. 1989. A Prosodic Theory of Epenthesis. *Natural Language and Linguistic Theory* 7: 217-259.

Itô, Junko and Armin Mester. 1999. Realignment. *The prosody-morphology interface*: 188-217.

Iverson, Gregory K. and Ahrong Lee. 2006. Perception of contrast in Korean loanword adaptation. *Korean Linguistics* 13(1): 49-87.

Jakobson, Roman. 1929. Über die heutigen Voraussetzungen der russischen Slavistik. Slavische Rundschau 1(8): 629-646.

Jakobson, Roman. 1941. *Kindersprache, aphasie und allegemeine lautgesetze*. Uppsala.

Jespersen, Otto. 1904. *Lehrbuch der Phonetik*. Leipzig/Berlin: Teubner.

Kay, Gillian. 1995. English loanwords in Japanese. *World Englishes* 14: 67-76.

Kiparsky, Paul. 1971. Historical linguistics. In W. O. Dingwall (ed.) *A Survey of Linguistic Science*. College Park: University of Maryland Linguistics Program. 576-642.

Kiparsky, Paul. 1973. Phonological representations. In O. Fujimura (ed.) *Three Dimensions of Linguistic Theory*. Tokyo: TEC. 3-136.

Kiparsky, Paul. I982. Lexical morphology and phonology. In I.-S. Yang (ed.) *Linguistics in the morning calm*. Seoul: Hanshin. 3-91.

Krakow, Rena A. 1999. Physiological organization of syllables: a review. *Journal of Phonetics* 27: 23-54.

Kreitman, Rina. 2010. Mixed voicing word-initial onset clusters. *Laboratory Phonology 10*, 4(4): 169-200.

Leben, William R. 1973. *Suprasegmental Phonology*. PhD dissertation, MIT.

Leben, William R. 1978. The Representation of Tone. In V. Fromkin (ed.) *Tone: A Linguistic Survey*. New York: Academic. 177-220.

Leben, William R. 1980. A metrical analysis of length. *Linguistic Inquiry* 11(3): 497-509.

Lieberman, Philip. 1960. Some acoustic correlates of word stress in American English. *Journal of the Acoustical Society of America* 32: 451-454.

Lleó, Conxita and Martin Rakow .2005. Markedness effects in the acquisition of voiced stop spirantization by Spanish–German bilinguals. *Proceedings of the International Symposium on Bilingualism* 4. Cascadilla Press Somerville, Massachusetts.

Marin, Stefania and Marianne Pouplier. 2010. Temporal organization of complex onsets and codas in American English: Testing the predictions of a gestural coupling model. *Motor Control* 14: 380-407.

Martinet, André. 1936. Neutralisation et archiphonème. Travaux du Cercle Linguistique de Prague 6: 46-57.

Maymon Yael. 2001. *Environmental influences on vowels in Hebrew*. M.A. thesis, Tel-Aviv University. (In Hebrew)

McCarthy, John. 1979. *Formal problems in Semitic phonology and morphology.* Doctoral Dissertation, MIT. Published 1985, New York: Garland.

McCarthy, John J. 1981. The representation of consonant length in Hebrew. *Linguistic Inquiry* 12(2): 322-327.

McCarthy, John J. 1986. OCP Effects: Gemination and Antigemination. *Linguistic inquiry* 17: 207-264.

McCarthy, John J. 1996. Remarks on phonological opacity in Optimality Theory. *Studies in Afroasiatic Grammar*. Papers from the Second Conference on Afroasiatic Linguistics, Sophia Antipolis, 1994. Jacqueline Lecarme, Jean Lowenstamm, and Ur Shlonsky (eds.). The Hague: Holland Academic Graphics, 215-243.

McCarthy, John J. and Alan Prince. 1993. *Generalized alignment*. University of Massachusetts, Amherst and Rutgers University MS.

McCarthy, John J. and Alan Prince. 1994. The emergence of the unmarked: Optimality in prosodic morphology. In Mercè Gonzàlez (ed.), Papers of the 24th Annual Meeting of the North Eastern Linguistic Society, 333-379. Amherst: GLSA.

McCarthy, John J and Alan Prince. 1995. *Faithfulness and reduplicative identity*. In Beckman, J., S. Urbanczyk & L. Walsh (eds.), *Papers in Optimality Theory [Occasional Papers 18].* 249-384.

Murray, Robert W. and Theo Vennemann. 1983. Sound change and syllable structure in Germanic phonology. *Language* 59: 514-528.

Padgett, Jaye. 1994. Stricture and Nasal Place Assimilation. *Natural Language and Linguistic Theory* 12: 465-513.

Parker, Stephen G. 2002. *Quantifying the sonority hierarchy*. Ph.D. thesis. University of Massachusetts, Amherst.

Pierrehumbert, Janet. 1994. Syllable Structure and Word Structure: A Study of Triconsonantal Clusters in English. In *Phonological structure and phonetic form: Papers in Laboratory Phonology* 3, Patricia Keating (ed.), 168-188. Cambridge: Cambridge University Press.

Prince, Alan S. 1975. *The phonology and morphology of Tiberian Hebrew*. Diss. Massachusetts Institute of Technology.

Prince, A. and P. Smolensky. 1993. *Optimality Theory: Constraint Interaction in Generative Grammar*. Ms, Rutgers University and University of Colorado, Boulder.

Pulleyblank, Douglas. 1986. Underspecification and low vowel harmony in Okpe. *Studies in African Linguistics* 17(2): 119-153.

Rialland, Annie. 1994. The Phonology and Phonetics of Extrasyllabicity in French. In *Phonological structure and phonetic form: Papers in Laboratory Phonology* 3, Patricia Keating (ed.), 136-159. Cambridge: Cambridge University Press.

Schein, Barry and Donca Steriade. 1986. On geminates. *Linguistic inquiry*, 17(4), 691-744.

Selkirk, Elisabeth. 1984. *Phonology and syntax*. Cambridge, Mass.: MIT Press.

Shaw, Jason A., Adamantios Gafos, Philip Hoole and Chakir Zeroual. 2009. Syllabification in Moroccan Arabic: evidence from patterns of temporal stability in articulation. *Phonology* 26: 187-215.

Sievers, Eduard. 1881. *Grundzüge der Phonetik*. Leipzig: Breitkopf & Härtel.

Steriade, Donca. 1982. *Greek Prosodies and the Nature of Syllabification*. Ph.D dissertation Cambridge, Mass: MIT.

Steriade, Donca. 1987. Redundant values. *Cls 23*(2): 339-362.

Steriade, Donca. 1988. Reduplication and Syllable Transfer in Sanskrit and Elsewhere. *Phonology* 5: 73-155.

Steriade, Donca. 1992. Complex Onsets as Single Segments. In J. Cole and C. Kisseberth (eds.), *Proceedings of the University of Illinois, Urbana Phonology Conference*. Stanford: CSLI.

Steriade, Donca. 1993. Closure, Release, and Nasal Contours. In M. Huffman and R. Krakow, eds., *Nasality (Phonetics & Phonology 5)*. New York: Academic Press.

Topintzi, Nina. 2008. On the existence of moraic onset geminates. *Natural Language & Linguistic Theory* 26(1): 147-184.

Trubetzkoy, Nicolai Sergeyevi. 1929. Polabische Studien. *Sitzungsberichte der Akademie der Wissenschaften in Wien*, Philosophisch-historische Klasse, Bund 211.

Trubetzkoy, Nicolai Sergeyevi. 1936. Essai d'une théorie des oppositions phonologiques. *Journal de psychologie normale et pathologique* 33:5-18.

Vennemann, Theo. 1988. *Preference Laws for Syllable Structure and the Explanation of Sound Change (With Special Reference to German, Germanic, Italian, and Latin).* Berlin: Mouton de Gruyter.

Vaux, Bert. 2004. The Appendix. *Symposium on Phonological theory: Representations and Architecture*, CUNY.

Wright, Richard. 2004. A review of perceptual cues and cue robustness. *Phonetically based phonology*, 34-57.

Zadok, Gila. 2012. *Similarity, variation, and change: Instability in Hebrew weak verbs*. Doctoral dissertation, Tel Aviv University.

תקציר

עבודת גמר זאת טוענת לקיומו של יחס חזק של יישור (*Alignment;* McCarthy and Prince 1993) בין עיצורים סותמים ויחידות פרוזודיות. על אף שמדובר ברעיון מוכר, ההצעה שאני מציג לוקחת בחשבון גם את התכונות התת-סגמנטליות כיעד לפעולת היישור. ליתר דיוק, אני טוען שנקודת הסגירה של עיצורים סותמים משתתפת בההיררכיה האוניברסלית של עיצורים שנדרשים "להתיישר" עם התחלה של יחידות פרוזודיות כדוגמת הברות. ההירככיה המוצעת של אילוצי יישור מוצגת במסגרת התיאורטית של תיאוריית האופטימליות (*Optimality Theory*; Prince and Smolensky 1993), באופן שמאפשר פתרון לסתירה הבאה: העיצור האופטימלי באונסט של הברה בסביבת VCV צפוי להיות סותם מטעמי מסומננות, אך הוא צפוי להיות חוכך בדקדוקים שיש בהם תהליכי ספירנטיזציה, גם כן מטעמי מסומננות.

נקודת מוצא לעבודה זאת מצויה במקרה מעניין של וריאציה (*variation*) בעברית מודרנית, בין עיצורים סותמים וחוככים (ר' Adam 2002). אני מציג ניסוי הפקה, המבוסס על מקרה זה של וריאציה כדי לאתר נטיות פונוטקטיות שדוברי עברית מציגים. אני מראה כיצד הירככיית היישור שהוזכרה קודם מסבירה את אחת הנטיות שעולות מהניסוי, ואני מציע מודל שבו הוריאציה בין סותמים לחוככים מוסברת באמצעות עקרון התת-מפרט (*Underspecification*; Kiparsky 1982), בנוסח ששואב השראה ממודל התת-מפרט של הארכיפונמה (*Archiphonemic Underspecification*; Inkelas 1995). לטענתי, המצב הסופי של מקרי הוריאציה בין סותמים לחוככים בעברית ניתן לחיזוי במקרים שבהם ישנה נטייה פונוטקטית להעדיף צורה מסויימת בעמדה שאחרי עיצור. זה מתאפשר באמצעות מנגנון אופטימיזציית הלקסיקון (*Lexicon Optimization*; Prince and Smolensky 1993) המונח ביסודו של מודל התת-מפרט של הארכיפונמה.

לבסוף, אני טוען שקיומה של הירככיית אילוצי היישור שאני מציע על בסיס עקרונות חיתוכיים, "מוסתרת" לעיתים קרובות על-ידי עקרון הסונוריות ש"נופח" בשל היותו עמום ואף שנוי במחלוקות (ר' Parker 2002 לסקירה מקיפה). אני משרבט בקצרה תוכנית להגדרה מחדש של סונוריות כעקרון המבוסס על עקרונות תפיסתיים (בשונה מחיתוכיים), המצוי במתאם פונטי עם היכולת הקוגניטיבית לתפוס טון (pitch). זה מבוסס, במידה מסוימת, על הצעות שעלו ב-Clements (2009). לאור זאת, אני מעלה מספר השערות ראשוניות לגבי השלכות וצפי שיש להגדרה כזאת של סונוריות ביחס למעמד של העיצורים השורקים (stridents) בתיאוריית הסונוריות, תוך התמקדות בהשלכות אפשריות שעולות ביחס לצרורות עם עיצורים שורקים (*S-Clusters*) וצרורות נוספים של סונוריות הפוכה (*reversed sonority*).

אוניברסיטת תל-אביב
הפקולטה למדעי הרוח ע"ש לסטר וסאלי אנטין
החוג לבלשנות

אוניברסלים פונוטקטיים בעברית מודרנית:
עדויות ליישור פרוזודי של סותמים

חיבור זה הוגש כעבודת גמר לקראת התואר
"מוסמך אוניברסיטה" (M.A.) באוניברסיטת תל-אביב

על-ידי
אביעד אלברט

העבודה הוכנה בהדרכת:
פרופ' אותי בת-אל וד"ר אוון כהן

נובמבר, 2014