Exceptionality and Variation in Modern Hebrew Spirantization

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1. Introduction

This paper examines exceptionality and variation phenomena in Modern Hebrew spirantization, and discusses their theoretical implications.

In Modern Hebrew, spirantization affects /b/, /p/, and /k/. These stops alternate with their fricative counterparts [v], [f], and [χ], respectively, in allophonic distribution, with the fricatives occurring post-vocalically and the stops occurring elsewhere (Adam 2002). An example of this distribution appears in (1), in a verbal paradigm in which /k/ is a regularly alternating segment, meaning that it surfaces as [k] word-initially and [χ] post-vocalically.

(1) Modern Hebrew spirantization distribution

/k/ → [χ] [**k**atav] 'wrote' [li**χ**tov] 'to write'

Due to historical mergers, degemination, and recent borrowings into Modern Hebrew, there are many exceptions to the spirantization distribution. These are manifested by the stops [b], [p], and [k] occurring post-vocalically or the fricatives [v], [f], and [χ] occurring non-post-vocalically. This is illustrated in (2) with paradigms in which the exceptional segment is realized in the same way regardless of position (with problematic cases for the spirantization distribution underlined).

(2) Exceptions to Modern Hebrew spirantization

a. /χ/ [**χ**alam] 'dreamt' [la**χ**lom] 'to dream'

b. /k/ [**k**ara] 'read' [li**k**ro] 'to read'

In (3), we present a 'hybrid' paradigm in which one segment of the root is regularly alternating and another is exceptional. The presence of an exceptional, non-alternating segment ([k], underlined) and a regularly alternating segment ([v] and [b], in bold) in a single paradigm suggests that this exceptionality is a segmental-level phenomenon. Any analysis of these exceptions, then, must treat the segment, rather than the word, as exceptional.

(3) 'Hybrid' cases in Modern Hebrew spirantization

[k] and [b]/[v] [ka**v**ar] 'buried' [lik**b**or] 'to bury'

In addition to cases of exceptionality, Adam (2002) discusses variation in the spirantization of the regularly alternating segments. This variation is instantiated by stops and fricatives occurring in contexts not predicted by the spirantization distribution, and reportedly varies across speakers and registers. However, unlike the exceptional cases in (2), these are segments that normally spirantize.

In view of the data presented above, this paper focuses on the need for a mechanism in the theory capable of handling exceptionality and variation, as well as regular allophonic distribution, simultaneously.

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2. Data

In this paper, the term Modern Hebrew refers to the non-Oriental colloquial variety of Hebrew currently spoken in Israel. Of the six supra-laryngeal stops in this variety, only /p/, /b/, and /k/ conform to the spirantization distribution outlined in (1).[1] The phonemic inventory, in (4), has all supralaryngeal stops outlined, with the spirantizing segments in bold. The fricative phonemes /f/, /v/, and /χ/ here are not those found in allophonic distribution with the bolded stops, but rather the exceptional segments mentioned in (2).

(4) Phonemic inventory of Modern Hebrew

	Bilabial	Labio-dental	Alveolar	Post-alveolar	Palatal	Velar	Uvular	Glottal
Stop	**/p/** **/b/**		/t/ /d/			**/k/** /g/		/ʔ/
Nasal	/m/		/n/					
Fricative		/f/ /v/	/s/ /z/	/ʃ/			/χ/	/h/
Approx.					/j/		/ʁ/	
Affricate			/ts/					
Lateral			/l/					

2.1. Allophony

Recall that spirantization in Modern Hebrew affects the phonemes /p/, /b/, and /k/, which surface as fricatives post-vocalically and as stops elsewhere. This allophonic relationship, which we refer to as the spirantization distribution, is illustrated in (5).

(5) Spirantization distribution in Modern Hebrew

Segment Pair	Root	Past (3p.sg.m)	Infinitive / Future (1p.sg)	
/p/ → [f]	/**p**rs/	[**p**aras]	[li**f**ros]	'spread'
			[e**f**ros]	'I will spread'
/b/ → [v]	/**b**nh/	[**b**ana]	[li**v**not]	'build'
			[e**v**ne]	'I will build'
/k/ → [χ]	/**k**tb/	[**k**atav]	[li**χ**tov]	'write'
			[e**χ**tov]	'I will write'

2.2. Exceptionality

Exceptions are manifested by non-alternating stops or fricatives. These are exceptional in that the stops may occur post-vocalically and the fricatives non-post-vocalically. Examples of such exceptions appear in (6), with the exceptional segment underlined.

[1] The other three stops – /t/, /d/, and /g/ – do not spirantize in Modern Hebrew due to language change. For an analysis of the lack of spirantization in these cases see Temkin Martínez (2005).

(6) Exceptions to Modern Hebrew Spirantization

a. [li<u>k</u>bor] ‘to bury’
b. [lesa<u>p</u>er] ‘to tell’
c. [leχa<u>b</u>el] ‘to sabotage’

d. [<u>f</u>iʃel] ‘mistook’
e. [<u>v</u>iter] ‘conceded’
f. [χalam] ‘dreamt’

The non-alternation of exceptional segments does not affect the distribution of other segments in the paradigm. This is seen in (7), which presents words containing both an exceptional segment (underlined), which has the same realization regardless of context, and a regularly alternating segment (in bold), which conforms to the spirantization distribution. We will refer to such lexical items as ‘hybrid’ forms. Hybrids demonstrate the need for exceptionality to be analyzed at the segmental level, because any analysis of exceptionality as a word-level phenomenon would (wrongly) predict that C1 and C2 in these words should either both be fixed in their continuancy or should both conform to the spirantization distribution.

(7) Hybrid forms with regard to spirantization in Modern Hebrew

Root	Past (3p.sg)	Infinitive	Gloss
C_1 alternates, C_2 is exceptional			
/**b**χn/	[**b**aχan]	[li**v**χon]	*‘examine’*
/**k**<u>b</u>d/	[**k**i<u>b</u>ed]	[le**χ**a<u>b</u>ed]	*‘honor’*
/**p**χd/	[**p**aχad]	[le**f**aχed]	*‘fear, scare’*
C_1 is exceptional, C_2 alternates			
/<u>k</u>**b**r/	[<u>k</u>a**v**ar]	[li<u>k</u>**b**or]	*‘bury’*
/χ**p**r/	[χa**f**ar]	[laχ**p**or]	*‘dig’*

2.3. Variation

In addition to exceptionality, there is variation in Modern Hebrew spirantization such that regularly alternating segments sometimes fail to conform to the spirantization distribution. This variation is mentioned in Adam (2002) as part of what she terms a variable grammar. The table in (8) lists some cases of variation discussed in Adam.

(8) Variation in Modern Hebrew spirantization (from Adam 2002)

Expected Form (by spirantization distribution)	**Acceptable Variant Form**	**Gloss**
pizer	**f**izer	*‘scattered’*
kisa	**χ**isa	*‘covered’*
jik**b**or	jik**v**or	*‘will bury’*
je**χ**ase	je**k**ase	*‘will cover’*

Temkin Martínez (2008) reports the results of an acceptability rating task designed to further explore Adam’s (2002) claims. The study found that variation exists in all regularly alternating consonant pairs and in all positions. In post-vocalic position, contrary to Adam’s data, there was a significant preference for the expected form for all consonant pairs. Moreover, the expected and variant segments were not rated equally in any of the pairs, suggesting this is not free variation. To account for this, then, there must be a way in which non-exceptional segments can systematically alternate contrary the spirantization distribution in (1).

3. Analysis

As we have seen, any analysis of Modern Hebrew spirantization must be able to handle allophony, exceptionality, and variation. Each of these is dealt with in turn below.

3.1. Allophony

The central constraint in the analysis of regularly spirantizing segments is one that prohibits stops post-vocalically. In order for this contextual markedness constraint to drive regular spirantization, it must dominate the relevant faithfulness constraint (Benua 1997).[2]

(9) Contextual markedness constraint driving spirantization
***V-STOP** Post-vocalic stops are prohibited.

Since spirantization involves alternation between stops and fricative, the relevant context-free markedness constraints for the current analysis are one that bans fricatives and another that bans stops, both of which are defined in (10).

(10) Context-free markedness constraints
***[+cont, -sib]** Non-sibilant fricatives are prohibited,[3]
***STOP** Stops are prohibited.

A faithfulness constraint for the feature [continuant] is ranked below the relevant markedness constraints, allowing markedness to drive the alternation while preventing input-output differences in continuancy that are not motivated by a dominating constraint.

(11) Faithfulness constraint for continuancy
IDENT-IO[cont] Let α be a segment in the input and β be a correspondent of α in the output. If α is [γF], then β is [γF] (McCarthy and Prince 1995). "Input-output correspondents are identical in [±cont]."

The relative ranking of these four constraints in the analysis of regularly alternating segments is shown in (12) and schematized in the tableaux in (13) and (14).

(12) Constraint Ranking for allophony: (Kager 1999)
***V-STOP » *[+cont, -sib] » IDENT-IO[cont], *STOP**

The ranking of the markedness constraints *V-STOP and *[+cont, -sib] above IDENT-IO[cont] ensures that the allophonic distribution of the stop-fricative pairs will be unaffected by the presence of either a stop or a fricative in the input. In the following tableaux, this is demonstrated through the use of hypothetical fricatives in the input for surface stops and hypothetical stops in the input for surface fricatives, possibilities made available by the principle of Richness of the Base.

Spirantization-driving contextual markedness dominates both context-free markedness constraint for fricatives and faithfulness for continuancy. As a result, post-vocalic stops surface as fricatives, as seen in (13):

(13) *V-STOP » *[+cont, -sib]

/**k**pr/ + (infinitive) *'to deny'*	*V-STOP	*[+cont, -sib]	IDENT-IO[cont]
☞a. li**χ**por		*	*
b. li**k**por	*!		

[2] cf. González (2003) and Kirchner (2004) for other lenition or spirantization-driving constraints.
[3] Ladefoged (1997) describes the need to distinguish sibilants from other fricatives, as they are distinct in acoustic features across the world's languages.

For stops to surface in non-post-vocalic position, the context-free markedness constraint against non-sibilant fricatives must be ranked higher than faithfulness for continuancy, thus blocking both post-consonantal and word-initial fricatives. Examples with stops in each of these contexts appear in (14a) and (14b), respectively:

(14a) *[+cont, -sib] » IDENT-IO[cont]

/χ**f**r/ + (infinitive) *'to deny'*	*V-STOP	*[+cont, -sib]	IDENT-IO[cont]
☞a. liχ**p**or		*	*
b. liχ**f**or		**!	
c. lik**p**or	*!		**

(14b) *[+cont, -sib] » IDENT-IO[cont]

/**χ**ns/ + (3p.past) *'gathered'*	*V-STOP	*[+cont, -sib]	IDENT-IO[cont]
☞a. **k**ines			*
b. **χ**ines		*!	

In exceptional cases, however, the ranking above does not allow the correct candidate to surface. In the tableaux in (15), we see that, due to the ranking of markedness over faithfulness, the candidate containing a word-initial stop or a post-vocalic fricative is (wrongly) selected as optimal in these paradigms (💣 denotes a wrongly selected candidate).

(15) Tableaux for exceptional, non-alternating segments

	*V-STOP	*[+cont, -sib]	IDENT-IO[cont]
A. /vtr/ + (3p.past) *'forgave'*			
a. viter	*	*!	
💣b. biter	*		*
B. /χpr/+ (3p.past) *'dug for'*			
a. χafar		**!	
💣b. kafar		*	*
C. /spr/+ (infinitive) *'to tell'*			
a. lesaper	*!		
💣b. lesafer		*	*

While re-ranking the constraints such that faithfulness dominates the two markedness constraints would correctly account for the exceptional cases in (15), it would prove fatal for the analysis of the regularly alternating segments shown in (13) and (14).

3.2. Exceptionality and the Set-Based Approach

Pater (2000) provides an analysis of lexical non-uniformity in English secondary stress. In this approach, exceptional words are coded for set membership. Constraints can be indexed to these sets. Each set, then, can have its own collection of indexed constraints. General (i.e. not lexically indexed) constraints are ranked in the same grammar as the set-indexed constraints, with different sets presenting potentially different rankings of their constraints. Exceptionality is captured by a faithfulness constraint that is indexed to the set of exceptional words dominating a process-driving markedness constraint. The markedness constraint in turn dominates the general version of the faithfulness constraint, causing non-exceptional words to show regular alternations. Pater also allows for variation by positing three sets of words: those that are consistently stressed, those that are consistently unstressed, and those that are variably stressed (whose indexed faithfulness constraint is ranked variably with respect to the relevant markedness constraint).

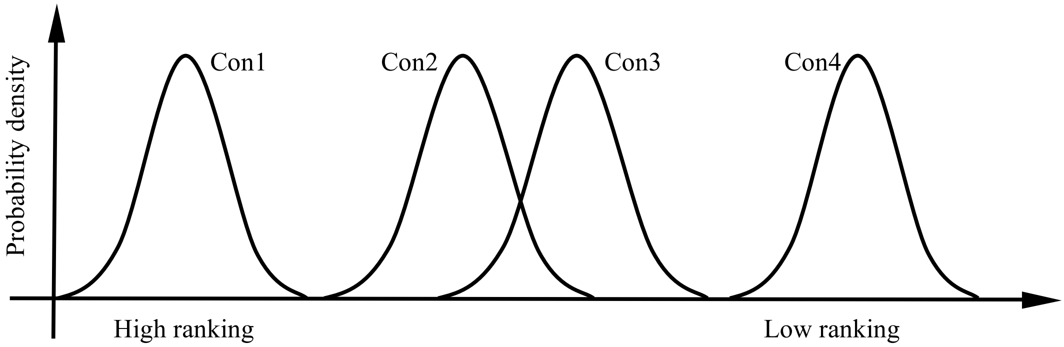
Traditional approaches to exceptionality, such as those of Itô and Mester (1999) and Pater (2000), treat exceptionality as a word-level phenomenon, requiring all segments in an exceptional word to behave exceptionally with respect to a given phenomenon. As a result, these approaches cannot account for hybrid forms such as [likbor], in which one segment behaves exceptionally with respect to spirantization while another does not. To remedy this, we propose extending the set-based approach to the segmental level to treat exceptionality in Modern Hebrew spirantization. In this extended analysis, every segment, in addition to being specified for its features, may be indexed to a set. This makes it possible to assign exceptional segments to a set with a corresponding, indexed, faithfulness constraint that dominates the markedness constraint in question. Regularly alternating segments, on the other hand, are not specified for set membership, leaving their realization to be determined by the interaction of the markedness constraints and general faithfulness constraints. Exceptional segments may also incur violations of these general constraints, but due to the dominating indexed faithfulness constraint, only the fully faithful candidate will be allowed to surface in these cases. The difference between regularly alternating and exceptional segments, then, is resolved by the exceptional segments being indexed to a version of the faithfulness constraint for continuancy that dominates the contextual markedness constraint banning post-vocalic stops.

3.3. Variation and Stochastic OT

In the current analysis, the difference between regularly alternating and variably alternating segments will be resolved by using stochastic ranking of the relevant markedness constraints. Prior to demonstrating the interaction of the set-based approach with stochastic ranking, we will provide a brief summary of Stochastic OT (Hayes & MacEachern 1998, Boersma 1998, Zuraw 2000, Boersma & Hayes 2001, Hayes & Londe 2006). Stochastic OT employs probabilistic ranking of constraints to account for variation and gradience. In this approach, each constraint is assigned a ranking value for any given utterance using the Gradual Learning Algorithm (GLA). The model, based on the GLA, assumes that grammar outputs are affected by lexical variant frequency, allowing for a variation in the output. The generated frequencies, though driven by the frequencies in the input (in this case, iterations of acceptability ratings from the rating task mentioned in 2.3), are not a mirror copy of them. Rather, the candidates are processed through the algorithm a high number of times, resulting in a generated frequency number that is then assigned to each of the candidates based on the interaction of the constraints that derive it. The value of the generated frequency will tend to correspond to the candidates' input frequency, such that candidates with high input frequency will tend to have relatively high generated frequency assigned by the GLA.

A schematic of a hypothetical constraint system showing the interaction and probabilistic ranking of four constraints appears in (16). In this example, the constraint Con_1 will very likely never be ranked lower than any of the other three, due to its high ranking value and lack of overlap. Similarly, it is highly unlikely that the constraint Con_4 will ever rank higher than any of the others due to its low ranking value and lack of overlap. The constraints Con_2 and Con_3, however, share similar ranking values and overlap in their probability densities. This means that their relative ranking is likely to vary, leading to variation in the output. Crucially, the relative ranking of these two constraints depends on probabilities based on variant lexical frequencies in the input.

(16) Hypothetical constraint system (adapted from Zuraw 2000)



For the current analysis, we used the GLA to generate frequencies based on the frequencies from the rating task, rather than assuming free variation (or exactly equal probability), allowing our model to capture variations with asymmetrical weightings.

3.4. The Combined Model

Combining the segmental set-based approach with stochastic ranking allows us to account for the Modern Hebrew data in the following ways. Firstly, the indexed faithfulness constraint is assumed not to be stochastically ranked, but rather to strictly dominate the markedness constraints driving spirantization, thus explaining the lack of variation in the non-alternating, exceptional segments. Secondly, the markedness constraints driving spirantization are assumed to be stochastically ranked with respect to one another, allowing for variation in the regularly alternating segments. Thirdly, in the case of the hybrid forms, which have both exceptional, non-alternating segments and regularly alternating ones, the exceptional segments are assumed to be indexed to a higher-ranked faithfulness constraint for continuancy, while the regularly alternating segments are subject only to the general, stochastically ranked markedness constraints that drive allophonic spirantization. Importantly, stochastic rankings are able to translate the preferences given to one form over another in the rating task into ranking values for the relevant constraints.

Based on the constraint violations entered for each of the variants, OTSoft (Hayes, Tesar & Zuraw 2003) generated ranking values for the constraints after testing the grammar through the Gradual Learning Algorithm for 2,000 cycles with a total of 50,000 learning trials. We determined the input frequencies for each candidate by dividing instances in which a variant was deemed acceptable by the sum of those instances of both forms of a given word. For example, 22 subjects rated the expected form [pizer] as acceptable, while only two subjects deemed its variant form [fizer] acceptable. With a total of 24 instances of acceptable ratings, [pizer] was deemed acceptable 92% of the time whereas [fizer] was deemed acceptable only 8% of the time. After entering the input frequencies for each of the 38 lexical items used in the task, OTSoft ran the grammar through the GLA and produced ranking values for each of the constraints used. Based on these values, four stochastic rankings were determined for the data set, presented in (17). Note that the indexed faithfulness constraint here contains a subscript A to indicate its indexation to the set of exceptional segments, Set A.

(17) Possible rankings predicted by the GLA in order of descending probability

IDENT-IO[cont]$_A$ » *V-STOP » *[+cont,-sib] » *STOP » IDENT-IO[cont]
IDENT-IO[cont]$_A$ » *V-STOP » *STOP » *[+cont, -sib] » IDENT-IO[cont]
IDENT-IO[cont]$_A$ » *[+cont, -sib] » *V-STOP » *STOP » IDENT-IO[cont]
IDENT-IO[cont]$_A$ » *STOP » *V-STOP » *[+cont, -sib] » IDENT-IO[cont]

The tableaux in (18) illustrate variation between the two possible realizations of the initial consonant in /pzr/. Using the GLA, the generated frequency for the two forms was 68.4% for the expected form [pizer] and 31.6% for the variant form [fizer]. Dotted lines between the constraints represent stochastic rankings.

(18) A. [pizer] *(expected, 68.4%)* ~ B. [fizer] *(variant, 31.6%)*
Stochastic ranking of *[+cont, -sib] and *STOP

A. /pzr/ + 3p.pst.m *'he scattered'*	IDENT-IO [cont]$_A$	*V-STOP	*[+cont, -sib]	*STOP	IDENT-IO [cont]
☞a. pizer				*	
b. fizer			*!		*

B. /pzr/ + 3p.pst.m *'he scattered'*	IDENT-IO [cont]$_A$	*V-STOP	*STOP	*[+cont, -sib]	IDENT-IO [cont]
a. pizer			*!		
☞b. fizer				*	*

Looking at a root with an alternating medial segment and no exceptional segments, (19) shows the need for a possible ranking in which the constraint against non-sibilant fricatives dominates the contextual markedness constraint driving spirantization. In (19), we see the expected form [ʃavar] and the variant [ʃabar], for which the GLA generated frequencies of 76% and 24%, respectively. The variant form derives the ranking of *[+cont, -sib] over *V-STOP with a stop occurring post-vocalically.

(19) A. [ʃavar] *(expected, 76%)* ~ B. [ʃabar] *(variant, 24%)*
Stochastic ranking of *V-STOP and *[+cont, -sib]

A. /ʃbr/ + 3p.pst.m *'he spread'*	IDENT-IO [cont]$_A$	*V-STOP	*[+cont, -sib]	*STOP	IDENT-IO [cont]
☞a. ʃavar			*		*
b. ʃabar		*!		*	

B. /ʃbr/ + 3p.pst.m *'he spread'*	IDENT-IO [cont]$_A$	*[+cont, -sib]	*V-STOP	*STOP	IDENT-IO [cont]
a. ʃavar		*!			*
☞b. ʃabar			*	*	

Finally, variation in hybrid forms can also be captured using this combined model by ranking the continuancy faithfulness constraint indexed to the set of exceptional segments above the relevant markedness constraints, requiring a faithful realization of the exceptional segment while allowing the regularly alternating segment to vary. In (20), we see how the combined model accounts for hybrid cases. Tableaux (20a) and (20b) demonstrate the need for stochastic ranking of the two context-free markedness constraints in the case of /kbr/, in which the alternating segment is root-medial and, in the infinitive form, occurs post-consonantally. Thus, the expected form [likbor] requires *[+cont, -sib] to dominate *STOP while the variant form [likvor] requires the opposite ranking of these two constraints. The indexed faithfulness constraint Ident-IO[cont]$_A$ is in a strict domination relation with the relevant markedness constraint to prevent the exceptional segment /k/ from alternating. The contextual markedness constraint against post-vocalic stops does not play a role in selecting the optimal candidate for this input since the only post-vocalic stop is exceptional.

(20) A. [likbor] *(expected, 68.4%)* ~ B. [likvor] *(variant, 31.6%)*
Stochastic ranking of *[+cont, -sib] and *STOP

A. /k$_A$br/ + inf. *'to bury'*	IDENT-IO [cont]$_A$	*V-STOP	*[+cont, -sib]	*STOP	IDENT-IO [cont]
a. lik$_A$vor		*	*!	*	*
☞b. lik$_A$bor		*		**	
c. liχ$_A$vor	*!		**		**
d. liχ$_A$bor	*!		*	*	*

B. /k$_A$br/ + inf. *'to bury'*	IDENT-IO [cont]$_A$	*V-STOP	*STOP	*[+cont, -sib]	IDENT-IO [cont]
☞a. lik$_A$vor		*	*	*	*
b. lik$_A$bor		*	**!		
c. liχ$_A$vor	*!			**	**
d. liχ$_A$bor	*!		*	*	*

4. Conclusion

In this paper, we have presented an analysis of allophony, exceptionality, and variation in Modern Hebrew spirantization within a single grammar. Our account handles both spirantizing and exceptional segments by extending the set-based approach of Pater (2000) to the segmental level. Exceptional segments (which do not vary) are assumed to be members of a set indexed to a faithfulness constraint that dominates the markedness constraints driving spirantization. Lastly, variation in regularly alternating segments, which was found in an acceptability rating task, is handled through stochastic ranking of the relevant markedness constraints.

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