The role of markedness in generalizing over lexical exceptions*

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Highlights:

- Regular allomorph selection is understood in OT to be done by markedness constraints, with no faithfulness cost. We extend this approach to irregular allomorph selection, using lexically-specific rankings of markedness constraints.
- We present results from an artificial language experiment with Hebrew speakers, showing that speakers prefer *product-oriented generalizations* (Albright & Hayes 2003) even in the absence of relevant evidence from the source language.
- We claim that speakers are biased by Universal Grammar to prefer product-oriented generalizations, as predicted by the analysis of allomorph selection in terms of markedness constraints.

1 The situation in Hebrew

Hebrew has two allomorphs of the plural suffix, [-im] and [-ot].

The learner can discover that [-im] is masculine and [-ot] is feminine by looking at nouns that take different plural suffixes according to natural gender, and then by the completely regular agreement on adjectives.

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(1) sus-ím horse-pl ktan-ím little-pl ‘little horses’

sus-ót horse-pl ktan-ót little-pl ‘little mares’

In the native vocabulary, however, masculine nouns can irregularly take [-ot], and feminine nouns can irregularly take [-im]. The true gender of the noun is revealed by agreement on adjectives (Aronoff 1994):

(2) xalon-ót window-pl ktan-ím small-pl ‘little windows’

(3) cipor-ím bird-pl ktan-ót small-pl ‘little birds’

In the loanword phonology, the plural suffixes don’t get stressed, and their selection is completely regular:

(4) blóg ∼ blóg-im ‘blog(s)’
banán-a ∼ banán-ot ‘banana(s)’

1.1 The lexicon

The masculine nouns that take [-ot] are not evenly distributed. Native masculine nouns from Bolozky & Becker (2006):

(5)

Final vowel	n	[ot]-takers	% [ot]-takers
u	1101	6	0.5%
i	464	8	1.7%
a	1349	39	2.9%
e	977	31	3.2%
o	523	146	27.9%
Total	4414	230	5.2%

Unsurprisingly, when given a masculine noun they haven’t heard before, Hebrew speakers like it better with [-ot] if it has an [o] in it (Berent et al. 1999, 2002; Becker 2009).

1.2 Learning Hebrew with Universal Grammar

In OT, allomorphs are selected by markedness constraints, with no faithfulness cost (Mester 1994, Mascaró 1996, Kager 1996, Anttila 1997, Hargus 1997, and more recently, Paster 2006, Wolf 2008, and Trommer 2008, among others).
The learner will identify [-im] as the masculine plural and [-ot] as the feminine plural, but will accept that the two affixes can compete for the same noun, even if its gender is known.

(6) ϕ-MATCH: Stems and affixes must agree in gender
(but see Wolf 2008 §2.4.2)

(7) LICENSE[o]: [o] must be either stressed or adjacent to a stressed [o]

(8) Taking [-im] to satisfy ϕ-MATCH

alon$_{MASC}$ + {im$_{MASC}$, ot$_{FEM}$}	ϕ-MATCH	LICENSE[o]
a. ☞ a l o n - í m		*
b. a l o n - ó t	*!	

(9) Taking [-ot] to satisfy LICENSE[o]

xalon$_{MASC}$ + {im$_{MASC}$, ot$_{FEM}$}	LICENSE[o]	ϕ-MATCH
a. ☞ x a l o n - ó t		*
b. x a l o n - í m	*!	

When faced with conflicting evidence about the ranking, speakers will clone one of the constraints (Pater 2006, 2008):

(10) LICENSE[o]$_{xalon}$ ≫ ϕ-MATCH ≫ LICENSE[o]$_{alon}$

And eventually, as the speaker learns all 523 Hebrew nouns with a final [o],

(11) LICENSE[o]$_{146\ items}$ ≫ ϕ-MATCH ≫ LICENSE[o]$_{377\ items}$

Given a novel native noun with [o] in it, the speaker will give it a 146/523 = 28% chance of taking [-ot].

(12) No reason to take [-ot] in loanwords

blóg$_{MASC}$ + {im$_{MASC}$, ot$_{FEM}$}	LICENSE[o]	ϕ-MATCH
a. ☞ b l ó g - i m		
b. b l ó g - o t		*!

1.3 Learning Hebrew without Universal Grammar

The Minimal Generalization Learner (MGL, Albright & Hayes 2002, 2003, 2006) learns morphology by creating rules of increasing generality:

(13)

	change	environment
[xalon] ∼ [xalonot]	Ø → [ot]	# x a l o n __ #
[aron] ∼ [aronot]	Ø → [ot]	# a r o n __ #
generalization:	Ø → [ot]	$\begin{bmatrix}+\text{son}\\+\text{cont}\end{bmatrix}$ o n __ #

The generalized rule can apply to any noun that ends in $\begin{bmatrix}+\text{son}\\+\text{cont}\end{bmatrix}$on, including an [im]-taker like [alon]. Each rule is associated with a success rate, or its rate of correct application.

As the MGL learns the nouns of Hebrew, it identifies two changes: Ø → [im] and Ø → [ot]. The environments for the two changes are different:

(14) Ø → [im] has a high success rate with [a], [e], [i], [u], and a somewhat lower success rate with [o]. But [a, e, i, u] don't make a natural class that excludes [o], so the general rule is: Ø → [im] / __ #.

(15) Ø → [ot] has a very low success rate with [a], [e], [i], [u], and a reasonable success rate with [o]. So we get two very general (sets of) rules:
(a) Ø → [ot] / __ # (low success rate)
(b) Ø → [ot] / o C __ # (reasonable success rate)

The learner discovers that having [o] in the root makes adding [ot] more likely.

1.4 With or without Universal Grammar?

The MGL takes a singular noun, and decides which change to apply to it. If the singular has [o] in it, it is more likely to take [-ot].

The OT-based learner creates a set of plural forms as candidates, and chooses the optimal one. If a plural has an unlicensed [o] in it, it is likely to be rejected.

The MGL makes its decisions based on changes between singulars and plurals (source-oriented). The OT-based learner makes its decisions based on plurals (product-oriented).

In real Hebrew, every noun that has [o] in its plural stem also has [o] in the singular, and almost every noun that has [o] in its singular stem keeps that [o] in the plural.

Real Hebrew is described equally well by both learners, because in real Hebrew, the [o] is present both in the singular and in the plural.

2 Artificial Hebrew

2.1 The languages

(16)

"surface" language		"deep" language	
amíg	amog-ót	amíg	amog-ím
axís	axos-ót	axís	axos-ím
azíx	azox-ót	azíx	azox-ím
aʃív	aʃov-ót	aʃív	aʃov-ím
adíc	adoc-ót	adíc	adoc-ím
apóz	apiz-ím	apóz	apiz-ót
agóf	agif-ím	agóf	agif-ót
acók	acik-ím	acók	acik-ót
abóʃ	abiʃ-ím	abóʃ	abiʃ-ót
alód	alid-ím	alód	alid-ót

Singulars are plausible native Hebrew nouns with an [o] or an [i] in their final syllable. In the plural stems, [o] alternates with [i] and vice versa.

The choice of the plural suffix agrees with the plural stem vowel in the "surface" language and with the singular stem vowel in the "deep" language.

After participants were trained and tested on one of the languages in (16), they were asked to generate plurals for the nouns in (17). The responses were rated for their success in applying the vowel changes and the selection of the plural affix.

(17) alíc, azíd, agív, apís, axíg, amíx, axíf, aníz, aʃík, afíʃ
abók, atóx, amóv, adós, aʃóg, aʃóc, aróf, ahóz, agóʃ, apód

The participants were 60 native speakers of Hebrew, who were students at the Hebrew University or at Tel Aviv University (average age: 23.4). Participants were randomly assigned to one of the two languages.

2.2 The predictions

Prediction of our markedness-based approach: When a speaker creates a plural form, the Universal constraint LICENSE[o] wants [o] to be licensed. It doesn't care what any vowels might have been in the singular.

(18) In the "surface" language, LICENSE[o] is always satisfied, because all plural stem [o]'s go with [-ot]. LICENSE[o] helps the speakers make the right choice.

(19) In the "deep" language, plural stem [o]'s go with [-im], causing a violation of LICENSE[o]. LICENSE[o] discourages the speakers from making the right choice.

The "surface" language is predicted to be easier than the "deep" language.

Prediction of the MGL: In real Hebrew, the two available changes are Ø → [im] and Ø → [ot]. In each artificial language, there are two different changes:

(20)

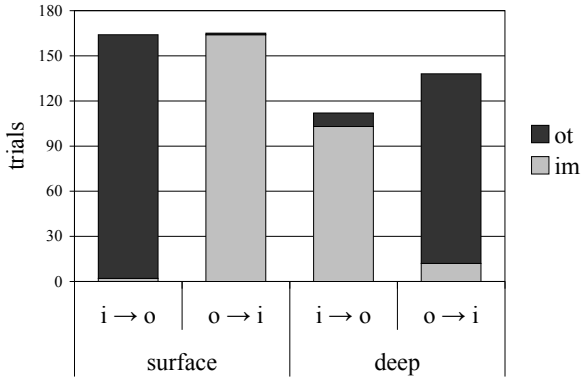
"surface" language	"deep" language
[o C] → [i C im]	[o C] → [i C ot]
[i C] → [o C ot]	[i C] → [o C im]

The changes of the artificial languages are not found in real Hebrew, and vice versa. Both the "surface" and the "deep" languages are equally distant from Real Hebrew, so they should be equally easy/hard to generalize.

2.3 Results

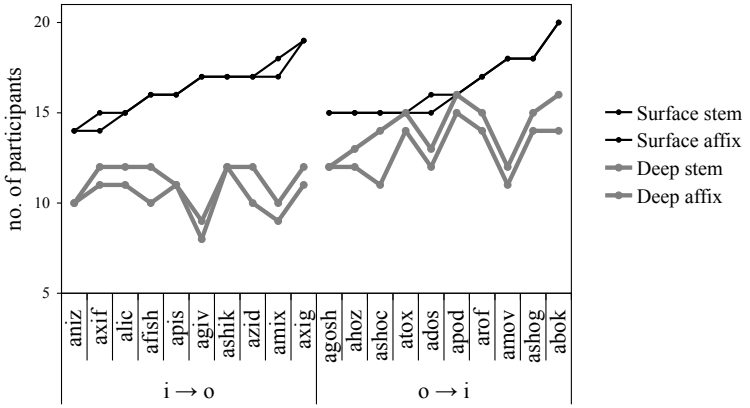
Speakers were more successful generalizing the "surface" language than the "deep" language. In the "deep" language, speakers were less successful with the [i] → [o] mapping relative to the [o] → [i] mapping.

(21) Trials with successful vowel changes



By-item analysis: same picture. Significantly more success with the "surface" group, for the stem vowel change (paired t-test, $t(19) = 7.36$, $p < .001$) and for the stem vowel change and affix selection (paired t-test, $t(19) = 9.25$, $p < .001$).

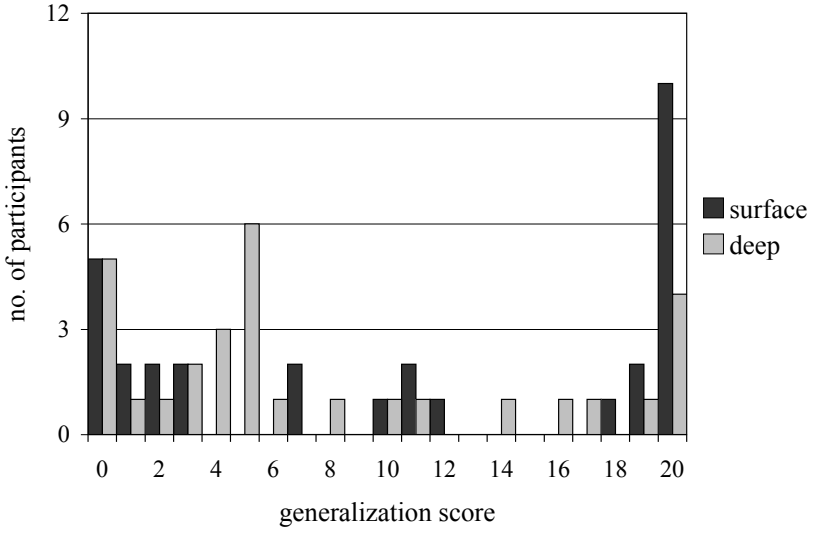
(22) Successful stem vowel change, with and without successful affix selection, by item



The "surface" group treats both vowel changes equally ($t(17.67) = .268$, $p > .1$). The "deep" group is significantly worse with [i]→[o] ($t(17.17) = 4.430$, $p < .001$).

The by-subject analysis shows an advantage for the "surface" participants, but the distribution is bimodal in both groups, so the stats are tricky.

(23) Successful stem vowel change and affix selection, by participant



At a cut-off point of 17, the difference between the groups is significant (Fisher exact test: odds ratio 3.736, $p < .05$). The choice of 17 for the cut-off point comes from the "surface" group, where no participant scored in the 13–17 range.

Mixed-effects logistic regression model, with *participant* and *item* as random effect variables:

(24)

	Estimate	SE	z	p
(Intercept)	0.761	0.723	1.054	0.292
"deep" language	−1.859	1.010	−1.843	0.065
singular [o]	0.091	0.286	0.317	0.752
"deep":singular [o]	0.658	0.374	1.760	0.078

The difference between the groups was not due to the random smartness of the "surface" language participants: Participants in both groups performed equally well on memorizing the singulars ($t(57.14) = .61$, $p > .1$).

2.4 The relevance to natural language

There is good reason to think that the participants were not only treating the artificial languages as an extension of real Hebrew, but specifically that they were treating the artificial items as masculine native nouns of Hebrew.

(25) Speakers invariably generated plural forms with *final stress*, proving that they were using their native Hebrew phonology, not their loanword phonology.

(26) Speakers chose [-im] 55.5% of the time, which is significantly more often than the expected 50% ($n = 60$, $M = .555$, Wilcoxon test with $\mu = .5$, $V > 1200$, $p < .05$). This shows that speakers treated the new words as masculine nouns, which are heavily biased towards [-im] in real Hebrew.

2.5 Summary

- Real Hebrew provides evidence for a correlation between having an [o] in the stem and taking the plural [-ot]. Real Hebrew does not provide evidence about the level of the generalization: Singulars, plurals, or the mappings between them.
- The markedness-based analysis predicts that speakers state the generalization over output forms, or plurals. We contrasted this with the MGL's rule-based analysis, which states the generalization over singular-plural mappings.
- When given an artificial language that puts [o]'s only in the singulars or only in the plurals, speakers prefer the language that pairs [-ot] with plural [o]'s.

3 OT analysis of the artificial languages

(27)

"surface" language		"deep" language	
amíg	amog-ót	amíg	amog-ím
apóz	apiz-ím	apóz	apiz-ót

In the "surface" language, stems with [o] always take [-ot], [-im] otherwise:

(28) Grammar for the "surface" language:
LICENSE[o] $\gg$ ϕ-MATCH $\gg$ *ó́/HIGH

The "surface" language is a simplified, regular version of real Hebrew.

In the "deep" language, stems with [o] take [-im]: ϕ-MATCH $\gg$ LICENSE[o].
But if stems without [o] take [-ot], then *ó́/HIGH $\gg$ ϕ-MATCH.
Which predicts that all nouns take [-ot], so there is no consistent grammar for the "deep" language.

(29) Possible grammar for the "deep" language:
ó́/HIGH$_{\{afiv,\ axis,\ amig,\ azix,\ adic\}}$ $\gg$ ϕ-MATCH $\gg$ *ó́/HIGH$_{\{agof,\ apoz,\ acok,\ abof,\ alod\}}$, LICENSE[o]

This grammar correctly predicts that [-im] will be selected 50% of the time, but this prediction is true *regardless of the vowel of the stem*. This grammar cannot be used to correlate the choice of plural suffix with the choice of stem vowel.

4 The role of phonotactics

In native masculine plural forms, [-im] is by far the most common. In the native plurals, disharmonic vowel sequences are more common than harmonic sequences.

(30) Prefinal vowels in native plural nouns

	Masculine	Feminine	Total
...o-ím	527	5	532
...i-ím	437	7	444
...o-ót	147	178	325
...i-ót	6	1070	1076

The greater frequency of disharmonic vowel sequences is apparent in roots, too:

(31) Vowel sequences in native singulars

	All singulars	Di-syllabic masculines
i-o	286	107
o-i	132	8
i-i	126	2
o-o	21	8

If speakers went by raw phonotactics, they would have preferred the "deep" language, which has disharmonic sequences on the surface.

5 Conclusions

- Hebrew speakers know that having [o] in the stem is conducive to choosing [-ot], but real Hebrew doesn't tell them whether this generalization is stated over singulars or singular-plural mappings (source-oriented) or over plurals (product-oriented).
- In an artificial language experiment that put [o] only in the singular or only in the plural, speakers preferred the correlation of [-ot] with a plural [o], i.e. they preferred a product-oriented generalization.
- The Universal bias for product-oriented generalizations follows naturally from an OT-based analysis that uses markedness constraints. The rule-based learner fails to predict the preference of the product-oriented language.

References

Albright, Adam & Bruce Hayes (2002). Modeling English past tense intuitions with minimal generalization. In Michael Maxwell (ed.) *Proceedings of the sixth meeting of the ACL special interest group in computational phonology*. Philadelphia: ACL, 58–69.

Albright, Adam & Bruce Hayes (2003). Rules vs. Analogy in English past tenses: a computationalexperimental study. *Cognition* **90**. 119–161.

Albright, Adam & Bruce Hayes (2006). Modeling productivity with the gradual learning algorithm: The problem of accidentally exceptionless generalizations. In Gisbert Fanselow, Caroline Féry, Matthias Schlesewsky & Ralf Vogel (eds.) *Gradience in Grammar*, Oxford University Press. 185–204.

Anttila, Arto (1997). *Variation in Finnish phonology and morphology*. Ph.D. dissertation, Stanford University, Stanford, CA.

Aronoff, Mark (1994). *Morphology by itself*. MIT Press.

Becker, Michael (2009). *Phonological Trends in the Lexicon: The Role of Constraints*. Ph.D. dissertation, UMass Amherst.

Berent, Iris, Steven Pinker & Joseph Shimron (1999). Default nominal inflection in Hebrew: Evidence for mental variables. *Cognition* **72**. 1–44.

Berent, Iris, Steven Pinker & Joseph Shimron (2002). The nature of regularity and irregularity: Evidence from Hebrew nominal inflection. *Journal of Psycholinguistic Research* **31**. 459–502.

Bolozky, Shmuel & Michael Becker (2006). Living Lexicon of Hebrew Nouns. Ms. UMass Amherst.

Hargus, Sharon (1997). Augmentation as affixation in athabaskan languages. *Phonology* **14**. 177–220.

Kager, René (1996). On affix allomor phy and syllable counting. In U. Kleinhenz (ed.) *interfaces in phonology*, Berlin: Akademie Verlag. 155–171.

Mascaró, Joan (1996). External allomorphy as emergence of the unmarked. In Jacques Durand & Bernard Laks (eds.) *Current Trends in Phonology: Models and Methods*, European Studies Research Institute, University of Salford. 473–483.

Mester, Armin (1994). The quantitative trochee in Latin. *Natural Language and Linguistic Theory* **12**. 1–61.

Paster, Mary (2006). *Phonological Conditions on Affixation*. Ph.D. dissertation, University of California, Berkeley.

Pater, Joe (2006). The locus of exceptionality: Morpheme-specific phonology as constraint indexation. In Leah Bateman & Adam Werle (eds.) *UMOP: Papers in Optimality Theory III*, Amherst, MA: GLSA. 1–36.

Pater, Joe (2008). Morpheme-specific phonology: Constraint indexation and inconsistency resolution. In Steve Parker (ed.) *Phonological Argumentation: Essays on Evidence and Motivation*, Equinox. 1–33.

Trommer, Jochen (2008). Syllable-counting allomorphy by indexed constraints. Talk given at OCP 5.

Wolf, Matthew (2008). *Optimal Interleaving: Serial Phonology-Morphology Interaction in a Constraint-Based Model.* Ph.D. dissertation, UMass Amherst.