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0.   Introduction

In this paper, we show that current interpretations of Lexicon Optimization (Prince and Smolensky 1993), in particular that of Archiphonemic Underspecification (Inkelas 1995), incorrectly predict the distribution of underspecification in lexical entries. We present cases from three vowel harmony languages in which speakers treat harmonic and disharmonic roots differently under reduplication. The assumption of full specification entails a ranking paradox, which can be resolved if underspecification is admitted in certain contexts not predicted by the principles of Lexicon Optimization. We point the way towards an expanded model of Lexicon Optimization that would both allow for and predict such cases of underspecification.

Transparency to spreading (or assimilation), susceptibility to spreading, failure to initiate spreading and various other special behavior prompted analysts working within a derivational model of phonology to hypothesize that certain featural specifications are absent for the relevant segments throughout at least a portion of the phonological derivation. Contrastive Underspecification (Steriade 1987) and Radical Underspecification (Archangeli 1984) were the dominant formal models designed to predict in a principled manner the incidence of underspecification. Contrastive Underspecification theory posited non-contrastiveness as the criterion for potential underspecification. A feature value might be missing from underlying representations if it failed to serve a contrastive function for the segment class in question. Under Radical Underspecification, the commitment to a redundancy-free lexicon had the consequence of eliminating all predictable feature values from underlying representations.

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Within Optimality Theory (Prince and Smolensky 1993), Richness of the Base specifically rules out the systematic exclusion of featural specifications from input representations. The input space is assumed to be infinite, thus unrestricted. The lexicon, by contrast, is assumed to be finite. A learner's construction of lexical representations is guided by Lexicon Optimization (Prince and Smolensky 1993), which heavily favors fully specified inputs. It is assumed that a speaker will choose the most harmonic input-to-output mapping. Outputs can be mapped to fully specified inputs without the accrual of gratuitous faithfulness violations. Given two competing input forms, one fully specified and one partially specified, the fully specified alternative will be preferred, all else being equal. The model nevertheless leaves room for the possibility that partially underspecified lexical entries will on occasion be posited.

Archiphonemic Underspecification (Inkelas 1995) seeks to predict when underspecified inputs will in fact be deployed. It demonstrates that the principles of Lexicon Optimization dictate that predictable feature values will be underspecified only when they enter into surface alternations. In a backness harmony language like Turkish, for instance, only those vowels that are involved in allophonic alternations will be underspecified for backness in lexical entries. In the words given in (1), all post-initial vowels agree in backness with the initial vowel. However, it is only the suffix vowels that both alternate and have a predictable value for backness. Archiphonemic Underspecification predicts that only they will be underspecified for backness, as indicated in (2):

(1)   Two words of Turkish
        a.   kilim-im   b.   kilic-im
                'rug-my'   'sword-my'

(2)   Assumed Lexical Representations
        a.   kilim-im   b.   kilic-im
                 | | | |
                -B -B   +B+B

This model essentially claims that harmony targets only suffix vowels in Turkish, because it is only for suffix vowels that a backness value lacking in the input representation is introduced in the corresponding output. Root vowels, whether harmonic or not, will be fully specified (and presumably identical) in input and output representations. Root vowels thus cannot be thought of as undergoing harmony at all. Clements and Sezer (1982, p. 226), motivated by entirely different theoretical considerations, take a similar position, stating that "...the burden of proof is on the linguist who wishes to demonstrate that roots [in Turkish] are governed by vowel harmony at all."

In this paper we present data that challenge the position advanced by Clements and Sezer and the predictions of Archiphonemic Underspecification. The patterns that we discuss indicate that harmony is indeed active within roots. Thus, we claim that the incidence of underspecification is not that which is predicted by Archiphonemic Underspecification. In particular, we introduce patterns of "re-harmonization" which
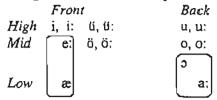
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demonstrate that speakers underspecify vowels not only in affixes but also in roots. The data involve the distinct treatment of harmonic and disharmonic roots in three harmony languages: Tuvan, a Turkic language of Siberia, Finnish and Turkish.

Before turning to the harmony data, we first discuss a case from Hungarian in which full specification, as required by Lexicon Optimization and Archiphonemic Underspecification, allows for the only correct account of the observed patterns. The feature values required to be lexically present for the purposes of the OT analysis are ones which pre-OT theories of underspecification would have explicitly predicted to be underlyingly absent.

1.   Hungarian Ubbi Dubbi [2]

The vowel inventory of Hungarian is given in (3). Vowel length is contrastive, as shown. Crucial to the argument developed below is the fact that the long and short variants of the vowels corresponding to orthographic <e> and <a> are qualitatively quite distinct. Long mid /e:/ corresponds to the short low vowel /æ/, and long unrounded /a:/ corresponds to the short rounded vowel /ɔ/.

(3)   Hungarian Vowel Inventory

	Front			*Back*
High	i, i:	ü, ü:		u, u:
Mid	e:	ö, ö:		o, o:
				ɔ
Low	æ			a:

Within the frameworks of both Contrastive Underspecification and Radical Underspecification, these quality differences would be probable candidates for underspecification due to their predictability from length (which is demonstrably contrastive for the vowel system of Hungarian as a whole). In Optimality Theory, however, the principles of Lexicon Optimization lead us to expect these quality differences to be explicitly recorded in lexical entries, rather than being left underspecified. The features in question are predictable but do not enter into surface alternations.

Evidence that this is in fact the case comes from a reduplicative word game similar to the English Ubbi Dubbi game. We will call this game "Hungarian Ubbi Dubbi," or "HUD." HUD works as follows. For a given word, a sequence /-Vv-/ is inserted before the rhyme of each syllable. The quality of the V is identical to that of the following vowel. The reduplicated vowel is always short, however, even when the following vowel is long. Some examples are supplied in (4):

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[2] "Ubbi Dubbi" is an English speech disguise game that was propagated by the 1970's children's television show "Zoom." The game works by inserting [əb] before the rhyme of each syllable within a word.

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(4)   Hungarian Ubbi Dubbi forms
           base   base+reduplicant   gloss
       a. itt   iv-itt   'here'
       b. ti:z   t-iv-i:z   'ten'
       c. sæm   s-æv-æm   'eye'
       d. e:r   ev-e:r, *æv-e:r   'vein'
       e. bɔb   b-ɔv-ɔb   'bean'
       f. a:r   av-a:r, *ɔv-a:r   'price'
       g. ne:vma:ʃ   n-ev-e:m-av-a:ʃ,   *n-æv-e:m-ɔv-a:ʃ 'pronoun'

Of particular importance are the forms shown in (4d, f and g). In each of these cases the reduplicants contain vowels that never surface outside the context of HUD. Datum (4d) contains short /e/ while (4f) contains short /a/. Datum (4g) contains instances of both of these otherwise non-surfacing vowels.

A Correspondence-based (McCarthy and Prince 1995) analysis of the pattern might run as follows. First, the absence of (*æ:, *e, *ɔ:, *a) in the general inventory of Hungarian can be represented as a constraint on inventory structure, given in (5):

(5)   Inventory Structure (*æ:, *e, *ɔ:, *a)   IS

Generally following the analysis of correspondence developed in McCarthy and Prince (1995), we invoke two faithfulness constraints, one requiring identity between input and output forms (IDENT-I/O) and the other requiring identity between base and reduplicant forms (IDENT-B/R):

(6)   Input-Output Identity   IDENT-I/O

(7)   Base-Reduplicant Identity   IDENT-B/R

Clearly, Base-Reduplicant Identity must outrank Inventory Structure. In order to ensure a quality-match between the vowels of the base and their reduplicant correspondents, the HUD forms allow otherwise unattested vowels (specifically /e/ and /a/) to surface. We will assume that Input-Output Identity ranks lowest, noting that the presence of illicit vowels in input representations never overrides Inventory Structure in this language.

To show how these constraints interact, let us consider a tableau for the word /e:r/, 'vein.' The reduplicants are underlined.

(8)   Tableau 1: Fully specified input

/eːr, RED/	Ident-B/R	IS	Ident-I/O
☞ a. ev-eːr		*(e)	
b. æv-æːr		*(æː)	*!
c. ev-æːr	*!	**(e, æː)	*
d. æv-eːr	*!		

Candidates (c) and (d) both violate Base-Reduplicant Identity, and are thus eliminated from consideration. Those candidates which satisfy Base-Reduplicant Identity tie with respect to Inventory Structure, each containing one illicit vowel. The decision is left to Input-Output Identity, which rules out candidate (b) by virtue of the disagreement between its base vowel and that of the input. This leaves us with the attested form /eveːr/.

Now consider what happens if the length-determined quality of the base vowel /e/, i.e., its precise height, is left underspecified in the input representation. Recall that pre-OT theories of underspecification would have called for the absence in lexical representations of this non-contrastive or redundant featural information. A tableau is shown in (9), where the capital "E" represents a non-high front vowel underspecified for the feature [low]:

(9)   Tableau 2: Underspecified input

/Eːr, RED/	Ident-B/R	IS	Ident-I/O
☞ a. ev-eːr		*(e)	
☞ b. æv-æːr		*(æː)	
c. ev-æːr	*!	**(e, æː)	*
d. æv-eːr	*!		

As indicated by the two pointing fingers, the grammar has no way of uniquely selecting the appropriate output (a). It chooses both (a) and (b). This inability stems from the absence of the relevant quality features in the specification of the input vowel.

We conclude from this example that, just as suggested by Lexicon Optimization, the mere predictability of a given feature value does not justify or mandate its exclusion from lexical representations. We should point out, however, that Richness of the Base states that the grammar should be capable of determining a well-formed output for *any* input, presumably even a partially-specified one such as that in (9). The grammar fails to do so, however. There is no context in which long /æː/ (or /ɔː/) surface in Hungarian, whether in the domain of HUD or otherwise.[3] So, candidate (b) from Tableau 2 is

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[3] A simple solution would be to separate the Inventory Structure constraint into two parts, one ruling out the ill-formed long vowels, *æː and *ɔː, and the other ruling out the ill-formed short vowels, *e

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illegitimate under any circumstances. One might attempt an explanation based on the claim that reduplication, as a morphological process, requires that the input contain a well-formed (i.e., fully specified) word. Under this view, an input such as that in Tableau 2 would never be submitted to the grammar for analysis.

This explanation cannot be correct, however, as we will show in the remainder of this paper. In the harmony cases to be discussed below, we show that speakers' performance in novel reduplicative tasks indicates that underspecified inputs such as that shown in Tableau 2 are indeed utilized. Moreover, the particular distribution of underspecified features is explicitly not that which the principles of Lexicon Optimization and Archiphonemic Underspecification would lead us to expect.

2.   Harmony, Reduplication and Re-harmonization

We now present empirical evidence from three vowel harmony languages—Finnish, Tuvan and Turkish—which poses a problem for the predictions of Archiphonemic Underspecification. In these languages, we argue, predictable segments must be underspecified even though they are non-alternating. We further argue that if non-alternating segments are underspecified then alternation is not an adequate diagnostic of underspecification. Our claim that speakers underspecify non-alternating segments rests on the different patterning of harmonic vs. disharmonic vowels in the novel context of reduplication and re-harmonization.

2.1   Tuvan Reduplication

Tuvan (Anderson and Harrison 1999) has an eight-vowel inventory, plus contrastive length.

(10)   Tuvan vowel inventory

	Front		Back	
High	i	ü	ɨ	u
Non-high	e	ö	a	o

Like most Turkic languages, Tuvan enforces strict backness harmony: only front vowels [i ü e ö] or back vowels [u ɨ a o] may co-occur within a word. Backness harmony is fully productive within roots and affixes. Nonetheless, the language tolerates a fair amount of disharmony in loanwords, native compound forms, and in one exceptional non-alternating morpheme. Tuvan also has rounding harmony, simply characterized by two basic principles: (i) the vowels [ö o] may not occur in post-initial syllables, and (ii) a high vowel must be rounded [ü u] when it follows any rounded vowel [ü u ö o], otherwise it must be unrounded. As we will show, harmonic and disharmonic vowels pattern differently under reduplication. Our claims about underspecification and harmony rest on

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and *a. If the constraint on long vowels outranks IDENT-B/R, then candidate (b) will be ruled out and only (a) will be selected. We doubt, however, that any independent justification for a particularly high ranking of *æː and *ɔː could be found.

this difference in patterning. In this paper, we limit our attention to backness harmony. The interaction of rounding harmony with reduplication is considerably more complex (Harrison 1999), but consistent with our general analysis.

Tuvan has a morphological process of full reduplication (Harrison 1999). Semantically, this type of reduplication contributes a sense of vagueness and/or jocularity to almost any lexeme in the language. Its use is restricted, however, to a subset of speakers and a special register, such that not all native speakers know how to do reduplication. Nonetheless, the process is sufficiently transparent that we were able to teach it to both adults and young children in a matter of seconds. Speakers who had just learned the rule were able to produce novel reduplicants and their output matched that of speakers who use reduplication regularly. Reduplication repeats the entire base while replacing the vowel of the initial syllable with a pre-specified [a] or [u].

(11)   Full reduplication of monosyllabic bases

	base	base + reduplicant	
a.	nom	nom-nam	'book'
b.	er	er-ar	'male'
c.	seek	seek-saak	'mosquito'
d.	is	is-as	'footprint'
e.	ög	ög-ag	'yurt'
f.	süt	süt-sat	'milk'
g.	qïs	qïs-qas	'girl'
h.	xol	xol-xal	'hand'
i.	at	at-ut	'name'
j.	aar	aar-uur	'heavy'

There is clearly a faithfulness relation between the base and reduplicant: except for the replacement vowel, the two are always identical. However, polysyllabic roots (along with any suffixal morphology) may be considerably less faithful to their base. In polysyllabic forms, post-initial vowels generally agree in backness with the replacement vowel. Note that since the replacement vowel is either [a] or [u], it is always [+back]. To achieve this agreement, speakers subject post-initial vowels to re-harmonization. To call attention to potential re-harmonization effects, we underline all post-initial vowels in reduplicants.

(12)   Full reduplication of polysyllabic bases with re-harmonization

a.	idik	idik-ad_ik_ (*ad_ik_)	'boot'
b.	fiidik	fiidik-faad_ik_ (*faad_ik_)	'video cassette'[4]
c.	teve	teve-tav_a_ (*tav_e_)	'camel'

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[4] Note that accidentally harmonic loanwords (e.g., 12b) also undergo re-harmonization, even though they may violate other phonotactic constraints of the language. For instance, Tuvan has no native phoneme [f], however the borrowed word *fiidik* is treated like any native, harmonic word with respect to re-harmonization. This suggests that an analysis invoking two grammars, one for native vocabulary and one for borrowed or foreign vocabulary, cannot be maintained.

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d.   tevelerim   tevelerim-tavalarim (*tavelerim)   'camel'-PL-1SG

Disharmonic segments, whether native or borrowed, fail to undergo re-harmonization, and remain disharmonic.

(13)   Full reduplication of polysyllabic bases with no re-harmonization
      a.   maʃina   maʃina-muʃina (*muʃina, *muʃuna)   'car'
      b.   ajbek   ajbek-ujbek (*ujbak)   'Ajbek'
      c.   ʒiguli   ʒiguli-ʒaguli (*ʒaguli,*ʒagulu)   'Zhiguli' (car name)
      d.   aal=ʒe   aal=ʒe-uul=ʒe (*uul=ʒa)   'yurt'=ALL

Adopting an Optimality Theoretic framework, we model Tuvan harmony and reduplication with the following constraints:

(14)   Constraints
      Morphological vowel replacement rule   REPLACE.V1
      Input-Reduplicant Identity   IDENT-I/R
      Harmony   ALIGN[BK][5]
      Base-Reduplicant Identity   IDENT-B/R

To begin, let's consider an input form such as *idik* 'boot'. In accord with the predictions of Lexicon Optimization, we assume a fully specified representation for this harmonic form, even though the backness value of the second vowel is predictable on the basis of the backness of the initial vowel. For *idik*, as for all harmonic words, the following constraint ranking allows us to capture the pattern of re-harmonization:

(15)   Ranking
      REPLACE.V1 >> ALIGN[BK] >> IDENT-I/R, IDENT-B/R

To show how these constraints interact, consider tableau 3, where we have included all but the Tuvan-specific morphological constraint.

(16)   Tableau 3: Harmonic form with fully specified input.

/idik, RED/ V -B	ALIGN[BK]	IDENT-I/R	IDENT-B/R
a. idik-adik	*!	*	*
☞ b. idik-adik		**	*!

The attested output form will only emerge if the harmony constraint ALIGN[BK] outranks both faithfulness constraints. This is due to the fact that the unattested candidate (a) is more faithful to the input, both in terms of IDENT-I/R and IDENT-B/R. Re-harmonization under reduplication provides ample evidence for the undominated status of the harmony constraint.

But for a disharmonic form with a fully specified input, the ranking shown in (15) selects the wrong candidate, as shown in tableau 4.

(17)   Tableau 4: Disharmonic form with fully specified input.

/ajbek, RED/ | | -B +B	ALIGN[BK]	IDENT-I/R	IDENT-B/R
☹ a. ajbek-ujbek	*!	*	*
☛ b. ajbek-ujbak		**	**

The attested disharmonic candidate (a) should win, but does not. For candidate (a) to win, the harmony constraint must rank below at least one of the faithfulness constraints. We thus propose an alternative ranking in which ALIGN[BK] ranks below input-reduplicant faithfulness. Again, we assume a fully specified input.

(18)   Tableau 5: Disharmonic form with fully specified input (new ranking)

/ajbek, RED/ | | +B -B	IDENT-I/R	ALIGN[BK]	IDENT-B/R
☞ a. ajbek-ujbek	*	*	*
b. ajbek-ujbak	**!		**

This ranking correctly selects the attested disharmonic form. We are thus faced with a ranking paradox by which harmonic and disharmonic sequences seem to require separate constraint rankings (i.e., separate grammars). This apparent paradox may be resolved if we allow harmonic words to be represented by underspecified inputs (contra the predictions of Lexicon Optimization and Archiphonemic Underspecification).

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(19)   Tableau 6: Harmonic form with underspecified input

/idik, RED/ | -B	IDENT-I/R	ALIGN[BK]	IDENT-B/R
a. idik-adik	*	*!	*
☞ b. idik-adik	*		**

Since disharmonic forms do not undergo re-harmonization (tableau 5), while harmonic forms do (tableau 6), we have assumed the former are fully specified for the harmonic feature and the latter are partially underspecified. Underspecification thus has a desirable result in that it obviates the need to posit separate constraint rankings for various subsets of the lexicon. Partial underspecification has the following consequence, illustrated in tableau 6. A violation is incurred only for the vowel of the initial syllable in both candidates. The underspecified non-initial vowels undergo "cost-free" re-harmonization (19b). In tableau 5, on the other hand, both vowels are fully specified such that an output which obeys harmony (18b), does so at a cost, namely the violation of input-reduplicant faithfulness. The same disparity in the treatment of harmonic and disharmonic vowels is found in Finnish (section §2.2) and Turkish (section §2.3).

2.2   Finnish Kontti Kieli

Facts similar to those of Tuvan have been documented in a Finnish reduplicative word game known as *kontti kieli* 'knapsack language' (Campbell 1986, Vago 1988). The game adds the word *kontti* 'knapsack' after a word, then preposes the initial (C)V sequences of each word. Speakers then re-harmonize the remaining vowels, with the exception of the neutral [e] and [i]. As in Tuvan, speakers re-harmonize harmonic words (a, b), but consistently fail to do so with disharmonic words (c, d). Potential re-harmonization targets are underlined in the data below.

(20)   Finnish *kontti kieli*
     a.   mitä kontti   →   ko-ta mi-ntti(*ko-tä)   'what'
     b.   sikiö kontti   →   ko-kio si-ntti (*ko-kiö)   'embryo'
     c.   konglööri kontti   →   ko-nglööri jo-ntti (*ko-ngloori)   'juggler'
     d.   manööveri kontti   →   ko-nööveri ma-ntti (*ko-nooveri)   'manouver'

Note that root vowels of Finnish never alternate except within the special context of *kontti kieli*. These results show that in the novel context of a language-external word game, speakers treat harmonic and disharmonic segments differently. Campbell (1986) used this to argue for the psychological reality of a rule of vowel harmony within Finnish, even in the face of numerous surface counter-examples to harmony. From our perspective, the Finnish data are comparable with Tuvan and may be analyzed in the same way, with the same implications.

We have claimed that speakers of vowel harmony languages such as Tuvan and Finnish underspecify predictable but non-alternating segments within roots. This claim entails that vowel harmony must be an active process even in cases where it appears to be little more than a static, phonotactic pattern. In Tuvan and Finnish, we have presented evidence that the quality of root vowels is established by means of alignment, except in the cases of disharmonic roots. We turn now to Turkish, where we extend our argument that harmony (rendered formally as alignment) actively determines feature values of all harmonic segments, even those that never enter into surface alternations. We show that Turkish vowel co-occurrence patterns within roots are not merely static, phonotactic patterns but active harmonic processes that have psychological reality and accessibility for speakers (contra Clements and Sezer 1982).

2.3   Turkish Root Harmony

Turkish lacks a Tuvan or Finnish-style process that would subject roots to novel alternations. Turkish root vowels thus never alternate in any context. As a pilot study, we taught a Tuvan-style reduplication rule to a speaker of Turkish. The speaker was instructed to replace the initial vowel of a set of Turkish words with [a] or [u]. He could then make any other changes—or no changes at all—to the reduplicant. The resulting form was to be a nonsense word that "sounds like a good Turkish word." The speaker produced multiple reduplicants for most bases; he then selected the best-sounding ones. Preliminary results of our pilot study show effects quite similar to those of Tuvan. The Turkish speaker showed a clear preference for re-harmonizing harmonic words (a, b), but not disharmonic words (c, d).

(21)   Turkish novel reduplication
    a.   kibrit   kibrit-kabrit (*kabrit)   'match'
    b.   bütün   bütün-batın (*batün, *batin) 'whole'
    c.   mali   mali-muli (*muli *mulü)   'Mali'
    d.   butik   butik-batik (*batik)   'boutique'

Our Turkish speaker, like Tuvan or Finnish speakers, apparently manipulated underlyingly unspecified segments by re-harmonizing them in this novel, reduplicative context. The fuller study of Turkish speakers' harmony preferences under reduplication will, we predict, provide additional empirical evidence that speakers of harmony languages underspecify predictable but non-alternating segments. They do so, we suspect, in response to an observed harmonic pattern attested in most (but by no means all) lexemes. The presence of a surface pattern of vowel co-occurrence in roots, in combination with regular alternations in suffixes is sufficient to drive speakers to posit a general system of vowel harmony that obtains across both roots and affixes.

3.   Pattern Responsive Lexicon Optimization (PRLO)

Speakers can thus arrive at underspecification by various means: the first would be as a result of predictable alternations, as in Turkish suffixes. Archiphonemic Underspecification correctly predicts that such cases will give rise to underspecification.

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A second way speakers can arrive at underspecification is essentially by analogy. Specifically, the presence of alternations in one part of the grammar (e.g., suffixes) in combination with segmental predictability in roots leads speakers to underspecify non-alternating root segments. We thus argue that it is an overall *pattern* of alternations, not morpheme-specific alternations, that triggers underspecification in lexical entries. A third type of situation that could trigger underspecification might be one that lacks any alternations but that shows a predictable pattern of surface distribution. This would be the case in a language having strict vowel co-occurrence patterns like those of Turkish and Tuvan, but lacking any affixal morphology.

We do not yet know whether a surface pattern alone, in the absence of any alternations, would provide "clear guidance" to speakers (see Yip 1998), inducing them to posit an active harmony process and to underspecify segments for the harmonic feature. We suggest that such a *pattern-responsive* system should be considered as a logical possibility and that further research should look for such patterns in phenomena such as tone, stress, reduplication and various types of harmony. Our goal is to construct a model of Lexicon Optimization that will allow us to characterize precisely the circumstances under which speakers will posit abstract lexical entries. An adequate theory of lexicon optimization should anticipate speakers' propensity to underspecify in response to surface-true patterns.

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