Deriving variation from grammar: A study of Finnish genitives

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Abstract

A way to derive morphological variation from UG principles is proposed. The specific problem discussed is the variable inflectional behavior of polysyllabic nouns in Finnish. An example is *naapuri*-GEN-PL 'neighbor' which has several surface variants, including *naapurien* and *naapureiden*. Building on Optimality Theory, I construct a grammar which predicts in what circumstances variation may and may not occur and which variant is preferred. Categorical outputs, variable outputs and statistical preferences follow from syllable prominence defined as a combination of stress, weight and sonority. Variation depends on how successfully these properties harmonize. If a stem gives rise to one very harmonic form, it shows no variation; if it yields several almost equioptimal alternatives, variation arises. Both categorical cases and variation are derived from one partially ranked grammar which yields multiple totally ranked tableaux. The number of total rankings by which a variant wins predicts its probability of occurrence.

1 Introduction

This study is an attempt to reconcile variation with generative phonology.[1] It arose out of the frustrating experiences I had establishing certain basic facts of Finnish phonology: rules that were absolutely central to the system sometimes applied with full force, sometimes they were optional. Solving the problem by labelling these rules "optional" did not even begin to work. It was hard to figure out the environments where optionality was supposedly invoked and, even worse, I soon began to realize that I was faced with optionality of the more–or–less sort: in many cases several variants were possible, but one of them was clearly preferred. The crucial problem was how to capture these gradient, yet robust facts in a generative framework. Given theoretical linguists' goal of moving away from rich descriptive devices towards restrictive theories, it was all the more puzzling to be faced with a phenomenon that current phonological theories seemed unable even to describe.

One alternative was to turn to a different research tradition: quantitative sociolinguistics. The Finnish problem was clearly a case of internally conditioned variation, something like the famous *-t, -d*-deletion in English, exept that the conditioning factors were apparently all phonological. The variable rule formalism (Labov 1969, Cedergren and Sankoff 1974) was clearly applicable to the data. I had two reservations about this move. First, a variable rule analysis would have provided a quantitative analysis of the residual cases that fell outside the categorical rules, but no explanation why the same phenomenon was obligatory in environments A, B and C, but optional in D, E and F. Why in just these environments and not others? Second, there was the problem of explaining preferences:

> Studies of linguistic variation have achieved a high level of quantitative precision in describing the systematic patterns of "orderly heterogeneity" (Weinreich et al. 1968, 100) that permeate human use of language. [...] With [variable rule] techniques and an impressive body of empirical studies completed, the field can be said to have achieved a certain level of descriptive adequacy. This descriptive precision is not generally matched, however, by explanatory precision. That is, the analyst usually cannot say *why* the quantitative values obtained should have the precise values they do. [...] Theories that predict particular quantitative values for linguistic variables are in very short supply in linguistics. The development of models that have explanatory value in this sense – models from which one can derive precise quantitative predictions – is one of the fundamental challenges facing our discipline (Guy 1991a, 1-2).

The approach to variation taken in this paper solves these problems. First, it accounts for variation in terms of a well-established generative model, Optimality Theory (OT) (Prince and Smolensky 1993) showing that there is no essential difference between categorical phenomena and variation; both follow from one and the same grammar expressed in a standard formalism familiar to phonologists. Second, the analysis explains why the same phenomenon is categorical in one environment, but variable in others: the answer is found in the rhythmic structure of words. Third, the model makes explicit quantitative predictions based on the interaction of grammatical principles in a way that provides a general solution to Guy's problem.

The present work is not the first one of its kind. An optimality-theoretic analysis of English *-t, -d*-deletion was proposed by Kiparsky (1993) which, to my knowledge, is the first systematic treatment of variation in OT literature and makes the connection between partial ranking and quantitative predictions. There are different ways to approach variation in OT; Liberman (1994) provides a useful discussion of various possibilities in connection with Latin morphology. Especially interesting is Hammond (1994) who, while not making any quantitative claims, provides an OT account of variable stress in Walmatjari. We shall see that Hammond's theory is fully compatible with the Finnish data and thus independently confirmed. Nagy and Reynolds (1994) and especially Reynolds (1994) give a range of OT-analyses for various languages, including a reanalysis of the *-t, -d* deletion facts, by means of "floating constraints".

The main theoretical goal of the present paper is to show how variation relates to categorical phenomena and how both derive from the interaction of grammatical principles. More specifically, we will explain morphological variation in terms of optimal syllable structure. The quantitative predictions were tested and confirmed on an on-line corpus of approximately 1.3 million words of written standard Finnish made available from the University of Helsinki Corpus Server.

2 The problem

The genitive plural is perhaps the thorniest descriptive problem in Finnish morphology. Karlsson (1982, 286) describes a handful of productively used allomorphs whose distribution is partly complementary, partly free. For the present purposes, I will adopt the traditional division into Strong and Weak forms.[2]

(1) Strong form: heavy penult (CVV, CVVC), final syllable onset /t, d/
Weak form: light penult (CV), final syllable onset /j/ or absent

a.	/puu/ 'tree'	**pui.d**en
	/potilas/ 'patient'	po.ti.**lai.d**en
b.	/kala/ 'fish'	ka.**lo.j**en
	/margariini/ 'margarine'	mar.ga.rii.**ni.**en
c.	/naapuri/ 'neighbor'	naa.pu.**rei.d**en ∼ naa.pu.**ri.**en
	/Reagani/ 'Reagan'	Rea.ga.**nei.d**en ∼ Rea.ga.**ni.**en
	/moskeija/ 'mosque'	mos.kei.**joi.d**en ∼ mos.kei.**jo.j**en
	/ministeri/ 'minister'	mi.nis.te.**rei.d**en ∼ mi.nis.te.**ri.**en

The genitive plurals of /puu/ and /potilas/ are invariably strong; this generalizes to all stems whose final syllable is heavy, which includes all monosyllabic stems. The genitive plurals of /kala/ and /margariini/ are invariably weak; this generalizes to all disyllabic stems and most stems with an even number of syllables, again setting aside those whose final syllable is heavy. The central problem we set out to solve in this paper is the puzzling free variation shown in (1c). Variation like this is rampant in CV-final stems which are at least three syllables long. It seems to have no lexical exceptions; variation is always permitted if the word is of the relevant prosodic shape. Most strikingly, this includes recent loans and foreign names.

Not unexpectedly, free variation is far from being totally free. Native speakers usually report that one variant sounds better than the other while agreeing that both variants are possible. These intuitions are independently confirmed by large corpora where the preferred variant is usually the more frequent one. What is puzzling, however, is that the preferred variant is sometimes weak, sometimes strong, depending on the stem. In view of this, it is no wonder that prescriptive grammarians have had a hard time fighting variation by recommending the usage of certain variants (Nirvi 1945).

In this paper, we shall give principled answers to the following questions:

(2) The locus of variation: Why does variation occur where it occurs? In the case of Finnish, why only in long words of a certain prosodic shape?

Degrees of variation: Why is one variant preferred over the other? How can grammars predict gradient intuitions?

Stability: Why has this fluctuation lasted for centuries without levelling out?

Variation is a notorious problem for generative theories of language structure. Especially problematic is the fact that variation is hardly ever totally free: the environment does not determine the variant categorically, yet it gives rise to a statistical bias. However, we shall see that as soon as the correct theoretical perspective is adopted, not only does variation and its absence turn out to be predictable, but even preferences are seen to follow from prosodic phonology.

2.1 Short stems and the stress factor

Let us first consider cases where the strong and weak variants are in a clean complementary distribution. In monosyllabic stems, the strong variant is chosen without exception. In disyllabic stems, the variants occur in complementary distribution: stems ending in a light syllable (CV) choose the weak variant, other stems choose the strong variant:

(3)	a.	/maa/ 'land'	**mai.d**en
		/tie/ 'road'	**tei.d**en
	b.	/kala/ 'fish'	ka.**lo.j**en
		/lasi/ 'glass'	la.**si.**en
	c.	/palttoo/ 'coat'	palt.**toi.d**en
		/varas/ 'thief'	var.**kai.d**en

In these short words, no variation emerges. The choice is uniquely determined by the number of syllables in the stem and/or the weight of the stem-final syllable. The data can be summarized as follows.[3]

(4) The distribution of strong and weak variants in short stems:

Stem length	Variant	-CVC, -CVV	-CV
1	Weak	0%	N/A
	Strong	100%	N/A
2	Weak	0%	100%
	Strong	100%	0%

What explains this pattern? The answer is word stress. In Finnish, stress assignment obeys two inviolable principles: main stress falls on the first syllable (Initial Stress) and two stressed syllables may not be adjacent (No Clash). Thus, the second syllable never receives stress. An explanation for the strong/weak pattern can now be given in terms of the following constraints which play a central role in Finnish phonology:

(5) a. PEAK PROMINENCE: Avoid stressed lights.
b. WEIGHT-TO-STRESS: Avoid unstressed heavies.

These constraints can be expressed in various ways, for example as implications: a. $\acute{\mathrm{X}} \rightarrow \mathrm{H}$ ('if stressed, then heavy'), b. $\mathrm{H} \rightarrow \acute{\mathrm{X}}$ ('if heavy, then stressed') or as starred structures: a. $*\acute{\mathrm{L}}$ ('stressed lights are bad'); b. *H ('unstressed heavies are bad'). These formulations are equivalent. What is important is that these constraints conspire to yield strong inflection for monosyllabic stems and weak inflection for disyllabic stems in the following way.

First, consider /maa/ which gives **mái.d***en* (the strong variant). The penultimate syllable is the initial syllable and thus stressed by INITIAL STRESS. As soon as this fact is established, PEAK PROMINENCE tells us this syllable must be heavy as well. This explains the strong variant. Second, consider /kala/ which yields *ká*.**lo.j***en* (the weak variant). This time, the penultimate syllable is the second syllable. By INITIAL STRESS and NO CLASH, the second syllable must be unstressed. As soon as this is established, WEIGHT-TO-STRESS guarantees that the penult must be light. This explains the weak variant. However, there is one systematic exception to this: if the disyllabic stem ends in a heavy syllable underlyingly, as in /palttoo/, *pált*.**toi.d***en* and /varas/, *vár*.**kai.d***en*), a strong genitive is selected even in absence of stress.

2.2 Long stems and the sonority factor

As soon as we get to trisyllabic stems, free variation arises. However, the variants are never on an equal footing. It turns out that stems ending in a high vowel /i, u, y/ prefer the weak variant, those ending in a low vowel /a, ä/ prefer the strong variant, and the mid vowels /o, ö/ are undecided between strong and weak. Again, if the stem-final syllable is underlyingly heavy (CVC or CVV), the strong genitive is chosen categorically. In the following table, the dispreferred variant is enclosed in brackets:[4]

(6)	a.	/lemmikki/ 'pet'	lem.mik.**ki.**en ~ (lem.mi.**kei.d**en)
		/sihteeri/ 'secretary'	sih.tee.**ri.**en ~ (sih.tee.**rei.d**en)
		/naapuri/ 'neighbor'	naa.pu.**ri.**en ~ (naa.pu.**rei.d**en)
	b.	/korjaamo/ 'repair shop'	kor.jaa.**mo.j**en ~ (kor.jaa.**moi.d**en)
		/fyysikko/ 'physicist'	fyy.sik.**ko.j**en ~ fyy.si.**koi.d**en
		/lokero/ 'compartment'	loke.**roi.d**en ~ (?lo.ke.**ro.j**en)
	c.	/sairaala/ 'hospital'	sai.raa.**loi.d**en ~ sai.raa.**lo.j**en
		/kamera/ 'camera'	ka.me.**roi.d**en ~ (?ka.me.**ro.j**en)
		/mansikka/ 'strawberry'	man.si.**koi.d**en ~ (?man.sik.**ko.j**en)

The judgments reported here are clearly reflected in actual usage. The following table is based on the *Suomen Kuvalehti 1987* corpus which contains approximately 1.3 million words of written standard Finnish (approximately 28,000 genitive plurals):[5]

(7) The final vowel effect (A = [+high,–low], O = [–high,–low], I = [–high,+low])

STEM LENGTH	VARIANT	-CVC, -CVV	-CA	-CO	-CI
3	WEAK	0% (0)	6.0% (49)	43.1% (352)	83.7% (1,174)
	STRONG	100% (3,598)	94.0% (766)	56.9% (465)	16.3% (228)
4	WEAK	0% (0)	0.4% (1)	77.1% (84)	96.1% (970)
	STRONG	100% (571)	99.6% (276)	22.9% (25)	3.9% (39)
5	WEAK	0% (0)	1.9% (2)	18.9% (10)	98.3% (114)
	STRONG	100% (244)	98.1% (101)	81.1% (43)	1.7% (2)

3-syllabic stems: $\chi^2 = 1,281.284, df2, p < .001$
4-syllabic stems: $\chi^2 = 1,081.848, df2, p < .001$
5-syllabic stems: $\chi^2 = 223.796, df2, p < .001$

What explains this correlation? The hypothesis we will pursue here is that, just as stress and weight are related, sonority and syllable weight have a natural affinity. In an ideal syllable, weight and nuclear sonority agree. Thus, *taa* is better than *tii* and *ti* is better than *ta*.

Curiously, the sonority effect only emerges in long words. If monosyllabic and disyllabic stems were sensitive to sonority we would expect the following (unattested) pattern where A-finals prefer strong, I-finals weak:

(8) a. /maa/ 'land' **mái.d**en
/kala/ 'fish' *ká.**loi.d**en
b. /puu/ 'tree' ***pú.j**en
/lasi/ 'glass' lá.**si.**en

As will be clear on the basis of earlier discussion, **pú.jen* and **ká.loi.den* are bad due to a mismatch of stress and weight. In the first case, initial stress dictates the strong variant *púi.den*. In the second case, the fact that stress can never fall on the second syllable implies the weak variant *ká.lo.jen*. The upshot is that, for some reason to be explained, stress overrides sonority.

2.3 Long stems and the alternating weight factor

Finally, variation is sensitive to the weight of the antepenultimate syllable (Itkonen 1979). The overarching generalization is that two syllables of identical weight should not collide. Other things being equal, H.L.H.L is a better word than H.H.H.H or L.L.L.L. Thus, antepenult and penult prefer to differ in weight. This effect only emerges with long stems.[6]

(9) /korjaamo/ 'repair shop' kor.**jaa.mo.j**en ~ (kor.**jaa.moi.d**en)
/lokero/ 'box' lo.**ke.roi.d**en ~ (?lo.**ke.ro.j**en)

Again, grammaticality judgments and corpus statistics agree. In the following table we can observe the effects of sonority and adjacent weight simultaneously. It turns out that weak variants tend to occur next to heavy antepenults and strong variants next to light antepenults:

(10) 3-syllabic stems: sonority and alternating weight

FINAL VOWEL	VARIANT	L__	H__
I = [+high, –low]	WEAK	26.2% (368)	57.5% (806)
	STRONG	15.3% (215)	0.9% (13)
O = [–high, –low]	WEAK	0.2% (2)	42.8% (350)
	STRONG	47.6% (389)	9.3% (76)
A = [–high, +low]	WEAK	0.5% (4)	5.5% (45)
	STRONG	88.3% (720)	5.6% (46)

I-final stems: $\chi^2 = 311.475, df1, p < .001$
O-final stems: $\chi^2 = 554.249, df1, p < .001$
A-final stems: $\chi^2 = 342.055, df1, p < .001$

(11) Examples:

I-FINAL, WEAK, L__: /naapuri/ 'neighbor' *naa*.**pu.ri.***en*
O-FINAL, WEAK, H__: /korjaamo/ 'repair shop' *kor*.**jaa.mo.j***en*
A-FINAL, STRONG, H__: /moskeija/ 'mosque' *mos*.**kei.joi.d***en*

4-syllabic stems follow essentially the same pattern:

(12) 4-syllabic stems: sonority and alternating weight

FINAL VOWEL	VARIANT	L__	H__
I = [+high, –low]	WEAK	23.2% (234)	72.9% (736)
	STRONG	3.9% (39)	0% (0)
O = [–high, –low]	WEAK	0% (0)	77.1% (84)
	STRONG	22.9% (25)	0% (0)
A = [–high, +low]	WEAK	0% (0)	0.4% (1)
	STRONG	99.6% (276)	0% (0)

One clear difference emerges: the combinations H+STRONG and L+WEAK which were disfavored in trisyllabic stems are now completely absent except when the stem-final vowel is /I/. In this case, the L+WEAK combination is rather common.

The fact that 5-syllabic stems follow suit proves the point beyond any reasonable doubt:

(13) 5-syllabic stems: sonority and alternating weight

FINAL VOWEL	VARIANT	L__	H__
I = [+high, –low]	WEAK	12.9% (15)	85.3% (99)
	STRONG	1.7% (2)	0% (0)
O = [–high, –low]	WEAK	0% (0)	18.9% (10)
	STRONG	77.4% (41)	3.8% (2)
A = [–high, +low]	WEAK	0% (0)	1.9% (2)
	STRONG	98.1% (101)	0% (0)

The combinations H+STRONG and L+WEAK are again absent exept in two environments. The L+WEAK combination is allowed if the stem-final vowel is /I/ (as in 4-syllabic stems). Furthermore, the H+STRONG combination is allowed in a very small number of cases (2). We will later see that our theory predicts the occurrence of H+STRONG in 5-syllabic words of a certain prosodic shape. These two examples fall into this category.

2.4 Summary

We now summarize the observations made in this section:

(14) Summary of variation possibilities:

Stem length	Stem-final syllable	Variant(s)
1 syllable	(irrelevant)	strong
2 syllables	heavy (CVV, CVC)	strong
	light (CV)	weak
3 syllables	heavy (CVV, CVC)	strong
	light (CV)	strong~weak
4 syllables	heavy (CVV, CVC)	strong
	light (CV)	strong~weak
5 syllables	heavy (CVV, CVC)	strong
	light (CV)	strong~weak

The absence of variation in short stems (1-2 syllables) was explained by the stress-related constraints Initial Stress, No Clash, Peak Prominence and Weight-to-Stress. The free variation attested with long stems (3-5 syllables) is not completely free, but is significantly affected by two factors: the sonority of stem-final syllable and the weight of the antepenult:

(15) Summary of variation preferences:

Stem-final vowel: /a, ä/ prefer strong, /i, y, u/ prefer weak.
Antepenult Weight: H-antepenults prefer weak, L-antepenults prefer strong.

How does all this relate to linguistic theory? With short stems, the variant is categorically determined by stress considerations; this is clearly something phonology should account for. A more intriguing question is what should be done with the longer words. The conditions are bona fide phonological environments, yet the resulting distribution is gradient, not categorical, and phonological theories capable of accommodating gradient facts are few and far between. However, if variation preferences are based on purely phonological variables, then it seems reasonable to expect phonology to make sense of them.

One alternative would be to compute the relative strength of each variable on the basis of the observed figures and propose a variable rule analysis for the long words. One might envisage a hybrid theory where the hard-and-fast phonological facts are handled by phonological constraints of the usual type and the gradient facts would be relegated to variable rules. However, this analysis would leave us puzzled about many questions. Why do vowel height and antepenult weight emerge in long instead of short words? Why is their effect gradient instead of categorical? Even more curiously, why are some long words completely immune to variation? It turns out that variation arises with (i) all

3-syllabic stems, (ii) 4-syllabic stems if the antepenult is L and the stem-final vowel /I/ and (iii) 5-syllabic stems if the antepenult is L and the stem-final vowel /I/ or if both the antepenult and the ante-antepenult are heavy. If this is the environment where the variable rule is supposed to apply, we have a problem rather than a solution.

The fact that variation is blocked in certain cases needs to be explained. It seems that these gaps somehow reflect the prosodic organization of Finnish words. If this is the case, then it is clearly incumbent upon phonology to explain why these gaps exist where they exist and, conversely, why variation arises where it arises. After having shown that this can be done, we will take one more step and show how the preferences in actual variation can also be derived from prosodic phonology.

3 Variation in Optimality Theory

In Optimality Theory (Prince and Smolensky 1993), a grammar consists of three parts: (i) a generation function GEN whose input is an underlying form and whose output is an infinite set of candidate forms derived from the input by unrestricted phonological operations, (ii) a set of universal constraints on the output of GEN and (iii) a general method for resolving constraint conflicts called strict dominance hierarchy or ranking.

Essentially, an OT-grammar is a partial order (ranking) on some constraint set. The ranking reflects the relative importance of constraints. Candidate forms (outputs of GEN) are evaluated against the ranked constraints and the candidate that best satisfies the constraints is the predicted surface form. If two variants compete, the variant which incurs the highest violation loses. Consider the following grammar:

(16) Grammar 1:

Constraints: A, B, C
Rankings: A $\gg$ B, B $\gg$ C, A $\gg$ C

This grammar imposes a total order on the constraints: A $\gg$ B $\gg$ C. Grammars are usually pictured as tableaux:

(17) Tableau 1: output = $cand_2$:

	A	B	C
a. $cand_1$	*	*!	
b. ⇒ $cand_2$	*		*

This tableau shows a competition between two candidates. Both violate the highest-ranking constraint A. This means that A cannot distinguish between the candidates (in the technical lingo, A is not *active* on the candidate set) and thus will not affect the output at all. The evaluation is passed on to constraint B. Since $cand_1$ violates B while $cand_2$ does not, $cand_2$ is more harmonic than $cand_1$ and wins. The fact that $cand_2$ violates constraint C while $cand_1$ does not is of no importance because B is ranked above C.

How does variation enter this picture? Clearly, it does not. Since $cand_1$ violates a higher constraint than $cand_2$ it loses categorically and only $cand_2$ is predicted. However, if grammar-induced variation is a fact of life there must be some way of modelling variation in OT. A simple solution would be to say that variation arises if the grammar is unable to decide between the candidates (the grammar is *inactive* on the candidate set). Suppose both candidates violate A and neither violates B nor C. The grammar is then unable to decide between the candidates, $cand_1$ and $cand_2$ are equally harmonic and both are predicted:

(18)

	A	B	C
a. ⇒ $cand_1$	*		
b. ⇒ $cand_2$	*		

This is truly the poor man's way of dealing with variation. As the candidates are equally harmonic there is no way of modelling such phonology-induced frequency effects we saw in the previous section. Something better is needed.

The grammar given in (16) was a partial order of a special kind: a total order. By removing one of the rankings, say B $\gg$ C, we obtain a genuine partially ordered grammar:

(19) Grammar 2:

Constraints: A, B, C
Rankings: A $\gg$ B, A $\gg$ C

The difference is that C is no more ranked with respect to B. If we want to picture this grammar as a tableau, we have two possibilities:

(20) Tableau 2.1: output = $cand_2$

	A	B	C
a. $cand_1$	*	*!	
b. ⇒ $cand_2$	*		*

(21) Tableau 2.2: output = $cand_1$

	A	C	B
a. ⇒ $cand_1$	*		*
b. $cand_2$	*	*!	

This example highlights the distinction between grammars and tableaux: one single grammar corresponds to two tableaux. What is more, the tableaux disagree about the winner: $cand_2$ wins by 2.1 and $cand_1$ by 2.2. Since the grammar permits both rankings, it also permits both outputs. In other words, it predicts variation.[7]

The remaining question is how preferences can be modelled. With this in mind, we display one more grammar. This one subsumes six totally ordered tableaux:

(22) Grammar 3:

Constraints: A, B, C
Rankings: none

(23) The corresponding tableaux:

$A \gg B \gg C$
$A \gg C \gg B$
$B \gg A \gg C$
$B \gg C \gg A$
$C \gg A \gg B$
$C \gg B \gg A$

If $cand_1$ violates constraints A and B and $cand_2$ violates C, then $cand_2$ will win in 2/3 of all tableaux. We propose the following interpretation:

(24) (a) A candidate is predicted by the grammar iff it wins in some tableau.

(b) If a candidate wins in n tableaux and t is the total number of tableaux, then the candidate's probability of occurrence is n/t.

In current OT practice, the grammar/tableau distinction is typically conflated by assuming that grammars are totally ordered. Prince and Smolensky (1993) mention "crucial nonranking" as a possibility provided by the theory, but remain agnostic about its role in grammar:

> We assume that the basic ranking hypothesis is that there is some total ranking which works; there could be (and typically will be) several, because a total ranking will often impose noncrucial dominance relations (noncrucial in that either order will work). It is entirely conceivable that the grammar should recognize nonranking of pairs of constraints, but this opens up the possibility of *crucial* nonranking (neither can dominate the other; both rankings are allowed), for which we have not yet found evidence. Given present understanding, we accept the hypothesis that there is a total order of domination on the constraint set; that is, that all nonrankings are noncrucial (Prince and Smolensky 1993, 51).

It is our contention that "crucial nonranking" is not just a technical quirk of OT, but that there exists a corresponding phenomenon in the empirical domain. This phenomenon is variation.

One of the most striking consequences of the present approach is that variation is not mentioned in the grammar at all. Since it equals absence of ranking it will arise automatically unless specifically blocked. One possible scenario is that in the initial state of language acquisition ranking is completely random and during the process of language acquisition rankings are set incrementally on the basis of positive evidence

(Tesar and Smolensky 1995). However, as the presence of variation shows, the task is not carried to completion and some amount of randomness persists to adult grammars.[8]

Partial ordering also offers a new perspective on the hypothesis that variation is due to competing grammars in the community or individual (Kiparsky 1993, Liberman 1994). Whether the present model is a competing grammars model reduces to the question of how a grammar is defined. If a grammar is defined as a total order then we have multiple grammars. If a partial order qualifies as a grammar we have a single grammar – in fact a very simple one. The simplest grammar would clearly be one with no rankings at all. A totally ranked grammar now seems like a curious anomaly; it is the most complex case and presupposes the greatest amount of learning.

Finally, the question arises whether we can reasonably expect to derive probabilities from pure grammar with any accuracy. Guy (1991a, 1991b) and Kiparsky (1993) are optimistic, Reynolds (1994, 136-7) less so:

> The claim I wish to emphasize here is that phonology itself should not be expected to provide us with [...] exact probabilities. These determinations must be made on the basis of empirical research, taking into account all of the various nonlinguistic factors – such as style, addressee, gender, age, and socioeconomic class – [...]

While this may be true in many cases, there seems little reason to decide a priori what the limits of phonological theory are. It is entirely possible that there exists variation which is not sensitive to style, addressee, gender, age or socioeconomic class, but is completely grammar-driven. To what extent extragrammatical factors are needed in deriving accurate statistics remains an empirical question.

4 The universal grammar of syllable prominence

We will now construct a grammar fragment which ties stress, weight and sonority together. Instead of proposing constraints as primitives, we start from three universal phonological scales:

(25) Universal prominence hierarchies:

Weight Hierarchy:	H > L
Stress Hierarchy:	X́ > X
Sonority Hierarchy:	A > O > I

Stress, weight and sonority, while phonologically clearly distinct, are known to share many properties both on phonetic and phonological levels.[9] We suggest that this is because these three scales are not just any arbitrary scales, but they are related in a particular way: they are all aspects of syllable prominence. In each scale, left is more prominent than right.

The intuition behind the present analysis can be stated as two simple phonological principles (to be made explicit later):

(26) (a) Prominence properties agree *within* the syllable.
(b) Prominence properties disagree *across* syllables.

By (a), syllables are preferably constructed in such a way that different prominence properties agree. Thus, *táa* and *ti* turn out to be the optimal syllables: stressed, heavy, sonorous and unstressed, light, unsonorous. As for (b), syllables are preferably combined in such a way that there are no prominence collisions. By this criterion, *táa.ti.táa.ti* is the ideal syllable sequence: stress is adjacent to no stress, heavy adjacent to light and high sonority adjacent to low sonority. Conflicts between requirements are resolved by ranking in the usual way.

In order to make these intuitions explicit, we identify the relation between the three scales with the optimality-theoretic notion of ALIGNMENT (Prince and Smolensky 1993, 127-172). This turns out to be a very useful move: as soon as we have established an alignment relation, OT yields the relevant constraints as a consequence, including rudimentary ranking:

(27) Definition: Alignment (Prince and Smolensky 1993, 136). Suppose given a binary dimension D_1 with a scale $X > Y$ on its elements $\{X, Y\}$, and another dimension D_2 with a scale $a > b > \ldots > z$ on its elements. The *harmonic alignment* of D_1 and D_2 is the pair of Harmony scales:

H_x: $\mathrm{X/a} \succ \mathrm{X/b} \succ \ldots \succ \mathrm{X/z}$
H_y: $\mathrm{Y/z} \succ \ldots \succ \mathrm{Y/b} \succ \mathrm{Y/a}$

The *constraint alignment* is the pair of constraint hierarchies:

C_x: $*\mathrm{X/z} \gg \ldots \gg *\mathrm{X/b} \gg *\mathrm{X/a}$
C_y: $*\mathrm{Y/a} \gg *\mathrm{Y/b} \gg \ldots \gg *\mathrm{Y/z}$

Two of the three prominence scales, WEIGHT and STRESS, are binary.[10] Applying the definition mechanically, we arrive at the following grammar fragment through an intermediary step of harmony scales:

(28) The universal grammar of prominence *within* the syllable:

a.	$\{*\mathrm{H}, *\acute{\mathrm{L}}\} \gg \{*\acute{\mathrm{H}}, *\mathrm{L}\}$	PEAK PROMINENCE, WEIGHT–TO–STRESS
b.	$*\mathrm{H/I} \gg *\mathrm{H/O} \gg *\mathrm{H/A}$	WEIGHT–SONORITY HARMONY
c.	$*\mathrm{L/A} \gg *\mathrm{L/O} \gg *\mathrm{L/I}$	WEIGHT–SONORITY HARMONY
d.	$*\acute{\mathrm{I}} \gg *\acute{\mathrm{O}} \gg *\acute{\mathrm{A}}$	STRESS–SONORITY HARMONY
e.	$*\mathrm{A} \gg *\mathrm{O} \gg *\mathrm{I}$	STRESS–SONORITY HARMONY

The resulting grammar consists of 16 partially ranked constraints. Each constraint encodes some combination of two prominence properties: weight and stress (a), weight and sonority (b, c) and stress and sonority (d, e). The higher the starred combination is ranked, the worse the structure is. Two examples: the ranking $*\mathrm{H} \gg *\acute{\mathrm{H}}$ conveys the information that *taa* is universally worse than *táa*; $*\mathrm{H/I} \gg *\mathrm{H/A}$ says that *tii* is worse than *taa*. Note that we have already seen many of these constraints operative in Finnish.

These constraints thus turn out to be direct consequences of Optimality Theory, given the alignment assumption.

As to the other half of (26), we stipulate the following constraints as primitives of UG. Since no ranking information is given, the constraints are assumed to float randomly inside the grammar, the null hypothesis.

(29) The universal grammar of prominence *across* syllables (generalized OCP):

a. *X́.X́, *X.X   No Clash, No Lapse
b. *H.H, *L.L
c. *A.A, *I.I

These constraints prohibit the collision of identical prominence values on each scale. No Clash and No Lapse enforce an alternating rhythmic stress pattern. *A.A and *I.I will not bear on the present analysis and will not be discussed further in this paper.[11]

5 Analysis

We now present an analysis of the Finnish facts. First, we show how three high-ranking constraints totally block variation in well-defined prosodic contexts explaining a range of systematic gaps in variation. In other contexts they are unable to decide between candidates and we end up with ties: it is here that variation *potentially* arises. Finally, we examine the residual where the grammar – due to random ranking – predicts several outputs, the *actual* variation.

The following inviolable constraints will be assumed although they will not appear in the tableaux:

(30) a. Initial Stress: The word-initial syllable is stressed.
b. *Final Stress: The word-final syllable is unstressed.

5.1 Categorical predictions

Ideally, the universal grammar fragment would suffice for Finnish and nothing else would have to be said. However, some rankings need to be added in order to predict the Finnish facts. Note that we are only adding rankings, thus elaborating on the basic ranking given by UG. The goal is to arrive at the Finnish pattern with as few additions as possible.

First, Finnish never permits two adjacent stressed syllables. In OT terms, this means that *X́.X́ (No Clash) is undominated. Second, recall that the two stress-related constraints, *Ĺ (Peak Prominence) and *H (Weight–to–Stress) were responsible for the categorical absence of variation with mono– and disyllabic stems, overriding sonority considerations. We modify the grammar by promoting *X́.X́ on top where it will always override any other constraint and the pair {*Ĺ, *H} to the second position where they dominate the rest of the grammar while themselves remaining mutually unranked. Essentially, we have divided the constraints into three sets which are strictly ranked with respect to each other, but internally random except for universal rankings:[12]

(31) The grammar for Finnish, preliminary version:

Set 1	Set 2	Set 3
*X́.X́	*Ĺ	*H/I ≫ *H/O ≫ *H/A
	*H	*Í ≫ *Ó ≫ *Á
		*L/A ≫ *L/O ≫ *L/I
		A ≫ O ≫ *I
		*L.L
		*H.H
		*X.X
		*H́
		*L

This simple ranking yields most of the categorical predictions. First, consider monosyllabic stems:

(32)

Tableau 1	*X́.X́	*Ĺ	*H	...
a. ⇒ H́.H			*	
b. Ĺ.H		*!	*	

Tableau 2	*X́.X́	*H	*Ĺ	...
a. ⇒ H́.H		*		
b. Ĺ.H		*	*!	

(33) /maa/ 'land': a. mái.den, b. *má.jen

The prediction is that only strong variants (heavy penults) are permitted. Permuting *Ĺ and *H does not matter: both tableaux make the same prediction. This is exactly the desired result: monosyllabic stems choose the strong variant and permit no variation.

We now turn to disyllabic stems. As the weight of the first syllable could not possibly matter, we simply write X. This time, the strong variant contains two violations of *H while the weak variant contains only one, and the latter wins categorically.[13]

(34)

Tableau 1	*X́.X́	*Ĺ	*H	...
a. ⇒ X́.L.H			*	
b. X́.H.H			**!	

Tableau 2	*X́.X́	*H	*Ĺ	...
a. ⇒ X́.L.H		*		
b. X́.H.H		**!		

(35) /kala/ 'fish': a. ká.lo.jen, b. *ká.loi.den

With trisyllabic stems we end up with a tie: the top constraints are unable to decide between the candidates. This means that we have a case of potential (and as we will see, actual) variation:

(36)

Tableau 1		*X́.X́	*Ĺ	*H	...
a.	⇒ X́.X.H̀.H			*	
b.	⇒ X́.X.L.H			*	

Tableau 2		*X́.X́	*H	*Ĺ	...
a.	⇒ X́.X.H̀.H		*		
b.	⇒ X́.X.L.H		*		

(37) /maailma/ 'world': a. máa.il.mòi.den, b. máa.il.mo.jen

The source of variation has now been discovered. The variation in (36) is made possible by the fact that secondary stress is strictly optional.[14] The grammar contains no constraint that would require the presence of secondary stress on any particular syllable. Since No Clash is irrelevant in the third syllable, primary stress being two syllables away, we have two alternatives: either the third syllable is stressed, hence heavy by *Ĺ, or unstressed, hence light by *H. All other options will be worse than these two. As a result, both strong and weak variants are predicted. This explains the extensive free variation with trisyllabic stems. We will later see how this tie is resolved in a quantitative fashion by partially ranked constraints further down the hierarchy.

The Finnish stress facts parallel the Walmatjari facts discussed by Hammond (1994). Hammond argues that the variability of stress placement in Walmatjari polysyllables can be captured by means of an incomplete constraint hierarchy. The fact that the same approach lends itself naturally to Finnish gives independent support to Hammond's thesis. However, unlike Hammond, we are in the position to extend the analysis to quantitative facts.

The behavior of longer stems provides the necessary independent test. The analysis predicts that inflection (both the presence/absence of variation and the strong/weak choice) will be sensitive to the sequencing of heavy and light syllables. A spectacular case confirming this prediction is the pair *ministeri* 'minister' and *margariini* 'margarine', both 4-syllabic *i*-final stems. Variation is correctly predicted only with the former. The crucial difference is the weight difference in the third syllable (/te/ = L vs. /rii/ = H):

(38)

Tableau 1			*X́.X́	*Ĺ	*H	...
1a.	⇒	X́.X.L.L.H			*	
1b.	⇒	X́.X.L.H̀.H			*	
2a.	⇒	X́.X.H̀.L.H			*	
2b.		X́.X.H̀.H.H			**!	
2c.		X́.X.H.H̀.H			**!	

Tableau 2			*X́.X́	*H	*Ĺ	...
1a.	⇒	X́.X.L.L.H		*		
1b.	⇒	X́.X.L.H̀.H		*		
2a.	⇒	X́.X.H̀.L.H		*		
2b.		X́.X.H̀.H.H		**!		
2c.		X́.X.H.H̀.H		**!		

(39) 1. /ministeri/ 'minister'
1a. mí.nis.te.ri.en
1b. mí.nis.te.rèi.den

(40) 2. /margariini/ 'margarine'
2a. már.ga.rìi.ni.en
2b. *már.ga.rìi.nei.den
2c. *már.ga.rii.nèi.den

If the third syllable is light, as in *mí.nis.te.ri*, we have a choice between a stressed penult (*mí.nis.te.rèi.den*) and an unstressed penult (*mí.nis.te.ri.en*) and both variants are predicted. This shows that *mí.nis.te.ri* is prosodically equivalent to a trisyllabic stem. If the third syllable is heavy, as in *már.ga.rìi.ni*, we have the prosodic equivalent of a disyllabic stem: the third syllable will be obligatorily stressed and the penult must be light which predicts the weak variant categorically. This explains three systematic gaps exhibited by 4-syllabic stems: a heavy antepenult systematically excludes strong variants, no matter the sonority of the final syllable. The table given in (12) shows the relevant statistics.

With 5-syllabic stems the predictions are subtler:

(41)

TABLEAU 1			*X́.X́	*Ĺ	*H	...
1a.	⇒	X́.X.X.L.H̀.H			*	
1b.	⇒	X́.X.X.L.L.H			*	
2a.	⇒	X́.X.H̀.H.L.H			**	
2b.	⇒	X́.X.H̀.H.H̀.H			**	
3a.	⇒	X́.X.L.H̀.L.H			*	
3b.		X́.X.L.H̀.H.H			**!	
3c.		X́.X.L.H.H̀.H			**!	

TABLEAU 2			*X́.X́	*H	*Ĺ	...
1a.	⇒	X́.X.X.L.H̀.H		*		
1b.	⇒	X́.X.X.L.L.H		*		
2a.	⇒	X́.X.H̀.H.L.H		**		
2b.	⇒	X́.X.H̀.H.H̀.H		**		
3a.	⇒	X́.X.L.H̀.L.H		*		
3b.		X́.X.L.H̀.H.H		**!		
3c.		X́.X.L.H.H̀.H		**!		

(42) 1. /Aleksanteri/ 'Alexander'
1a. Á.lek.sàn.te.rèi.den
1b. Á.lek.sàn.te.ri.en

(43) 2. /koordinaatisto/ 'coordinate grid'
2a. kóor.di.nàa.tis.tòi.den
2b. kòor.di.nàa.tis.to.jen

(44) 3. /italiaano/ 'Italian'
3a. í.ta.li.àa.no.jen
3b. *í.ta.li.àa.noi.den
3c. *í.ta.li.aa.nòi.den

/Aleksanteri/ and /koordinaatisto/ permit variation just like trisyllabic stems. With /italiaano/ the weak variant is categorical. This generalizes to all cases where ante-antepenult is L and antepenult H. As (3abc) shows, this is because stress has to skip the light third syllable and land on the heavy fourth which blocks weight variation in the fifth syllable.[15]

5.2 Summary of categorical predictions

We have now explained why mono- and disyllabic stems never permit variation; why 3-syllabic stems vary in all categories; why 4-syllabic stems only vary after a light antepenult; and why 5-syllables are a mix between 3– and 4–syllabic types in allowing free variation after light antepenults and limited variation after heavy antepenults. This apparently complex statement has been reduced to UG augmented by three Finnish-specific rankings: the elevation of *X́.X́ to an undominated status and the promotion of *Ĺ and *H to the second position in the grammar.

(45) Possible variation types with examples:

a.	X́.X.**H̀**.H	náa.pu.rèi.den
	X́.X.**L**.H	náa.pu.ri.en
b.	X́.X.L.**H̀**.H	mí.nis.te.rèi.den
	X́.X.L.**L**.H	mí.nis.te.ri.en
c.	X́.X.X.L.**H̀**.H	Á.lek.sàn.te.rèi.den
	X́.X.X.L.**L**.H	Á.lek.sàn.te.ri.en
d.	X́.X.H̀.H.**H̀**.H	kóor.di.nàa.tis.tòi.den
	X́.X.H̀.H.**L**.H	kóor.di.nàa.tis.to.jen

The analysis of course extends beyond these data and predicts the variation behavior of arbitrarily long stems. In practice, Finnish runs out of simple stems at 7 syllables.

(46) /intellektuelli/ 'intellectual'
a. ín.tel.lèk.tu.èl.li.en
b. *ín.tel.lèk.tu.èl.lei.den

(47) /eksistentialisti/ 'existentialist'
a. ék.sis.tèn.ti.a.lìs.ti.en
b. *ék.sis.tèn.ti.a.lìs.tei.den

5.3 Quantitative predictions

The variation space defined by weight and stress constraints turns out to be unevenly populated. For example, the following trisyllabic stems have very different variation profiles:

(48)

	STEM	VARIANTS	MOTIF	OBS. FREQ.
a.	kamera	?ká.**me.ro**.jen	L.TA	0.6%
	'camera'	ká.**me.ròi**.den	L.TÁA	99.4%
b.	sairaala	sái.**raa.lo**.jen	H.TA	49.5%
	'hospital'	sái.**raa.lòi**.den	H.TÁA	50.5%
c.	naapuri	náa.**pu.ri**.en	L.TI	63.1%
	'neighbor'	náa.**pu.rèi**.den	L.TÍI	36.9%
d.	korjaamo	kór.**jaa.mo**.jen	H.TO	82.2%
	'repair shop'	kór.**jaa.mòi**.den	H.TÓO	17.8%

The column labelled MOTIF shows a schematic picture of the antepenult and penult. First, consider /kamera/. The heavy bias towards the strong variant is due to the fact that L.TÁA is a perfect structure: all the prominence properties within the penult agree, neither are there any prominence clashes between the two syllables. In contrast, the competing variant L.TA is faulty in several ways.

In the remaining examples, none of the variants is perfect. They display an assortment of syllable-internal violations such as stress–sonority and weight–sonority mismatches plus weight collisions between antepenult and penult. However, no single violation is by itself bad enough to resolve the competition and the battle of constraints results in a gradient output. This shows that the decisive constraints must be randomly ranked. To achieve these results, we establish two intermediary constraint sets:

(49) {*L.L, *H/I, *Í} ≫ {*L/A, *H/O, *Ó, *H.H, *X.X, *Ḣ}

While mutually ranked, the sets are internally random reflecting the fact that the constraints are equally important in the linguistic system of Finnish. This forms the probabilistic component of the grammar.

(50) The grammar for Finnish, final version

SET 1	SET 2	SET 3	SET 4	SET 5
*X́.X́	*Ĺ	*H/I	*H/O	*H/A
	*H	*Í	*Ó	*Á
		*L.L	*L/A	*L/O ≫ *L/I
			*H.H	*A ≫ *O ≫ *I
			*H́	*L
			*X.X	

As an example, consider the tie between L.TI and L.TÍI exemplified by *náa.pu.ri.en* and *náa.pu.rèi.den*. To compute the result, we spell out the six tableaux hidden in SET 3. The ratio of victories, 4/2 for the weak variant, closely corresponds to the observed ratio (63.1%/36.9%).

(51)

Tableau 1	...	*H/I	*Í	*L.L	...
1a. L.TÍI		*!	*		
1b. ⇒ L.TI				*	

Tableau 2	...	*H/I	*L.L	*Í	...
1a. L.TÍI		*!		*	
1b. ⇒ L.TI			*		

Tableau 3	...	*Í	*L.L	*H/I	...
1a. L.TÍI		*!		*	
1b. ⇒ L.TI			*		

Tableau 4	...	Í	*H/I	*L.L	...
1a. L.TÍI		*!	*		
1b. ⇒ L.TI				*	

Tableau 5	...	*L.L	*H/I	*Í	...
1a. ⇒ L.TÍI			*	*	
1b. L.TI		*!			

Tableau 6	...	*L.L	*Í	*H/I	...
1a. ⇒ L.TÍI			*	*	
1b. L.TI		*!			

Drawing the tableaux was in fact unnecessary. Since ranking is totally random, knowing that the weak variant violates one constraint (*L.L) while the strong variant violates two (*H/I, *Í) gives us the result directly. The quantitative predictions are now easy to compute for all types.

(52)

	Motif	Set 3	Set 4	Result
1a	L.TÁA		...	wins in all
1b	L.TA	*L.L	...	loses in all
2a	L.TÓO		...	wins in all
2b	L.TO	*L.L	...	loses in all
3a	L.TÍI	*H/I, *Í	...	wins in 1/3
3b	L.TI	*L.L	...	wins in 2/3
4a	H.TÁA		*H.H, *Ĥ	wins in 1/2
4b	H.TA		*L/A, *X.X	wins in 1/2
5a	H.TÓO		*H/O, *Ó, *H.H, *Ĥ	wins in 1/5
5b	H.TO		*X.X	wins in 4/5
6a	H.TÍI	*H/I, *Í	...	loses in all
6b	H.TI		...	wins in all

(53) Predictions and observed frequencies: 3-syllabic stems

	MOTIF	PRED. %	OBS. %	EXAMPLES
1a	L.TÁA	100	99.4 (720)	ká.me.ròi.den
1b	L.TA	0	0.6 (4)	ká.me.ro.jen
2a	L.TÓO	100	99.5 (389)	hé.te.ròi.den
2b	L.TO	0	0.5 (2)	hé.te.ro.jen
3a	L.TÍI	33	36.9 (215)	náa.pu.rèi.den
3b	L.TI	67	63.1 (368)	náa.pu.ri.en
4a	H.TÁA	50	50.5 (46)	máa.il.mòi.den
4b	H.TA	50	49.5 (45)	máa.il.mo.jen
5a	H.TÓO	20	17.8 (76)	kór.jaa.mòi.den
5b	H.TO	80	82.2 (350)	kór.jaa.mo.jen
6a	H.TÍI	0	1.6 (13)	pó.lii.sèi.den
6b	H.TI	100	98.4 (806)	pó.lii.si.en

In (1ab), it might seem surprising that the seriously disharmonic L.TA manages to beat the perfect candidate in 0.6% of the cases. A closer look shows that these counterexamples are all artefacts of spelling. They all involve one word /kollega/ 'colleague' which appears in the (normatively correct) form *kollegojen* 4 times in the corpus. This form is generally pronounced *kolleegojen* with a heavy antepenult and also spelt that way twice in this corpus. In (2ab), the two unexpected tokens are *hé.te.ro.jen* 'hetero' and *í.ma.go.jen* 'image' which go unexplained here. The 13 strong forms in (6ab) seem to be genuine problems. However, as the quantitative predictions of our model are discrete probabilities (1/2, 1/3, 1/5 etc.) it would be difficult to get any closer. A more fine-grained grammar with more constraints might remedy this shortcoming.

(54) Predictions and observed frequencies: 4-syllabic stems

	MOTIF	PRED. %	OBS. %	EXAMPLES
1a	L.TÁA	100	100 (276)	tái.tei.li.jòi.den
1b	L.TA	0	0 (0)	–
2a	L.TÓO	100	100 (25)	lú.et.te.lòi.den
2b	L.TO	0	0 (0)	–
3a	L.TÍI	33	14.3 (39)	mí.nis.te.rèi.den
3b	L.TI	67	85.7 (234)	mí.nis.te.ri.en
4a	H.TÁA	0	0 (0)	–
4b	H.TA	100	100 (1)	lúon.neh.dìn.to.jen
5a	H.TÓO	0	0 (0)	–
5b	H.TO	100	100 (84)	é.dus.tùs.to.jen
6a	H.TÍI	0	0 (0)	–
6b	H.TI	100	100 (736)	már.ga.rìi.ni.en

With 4-syllabic stems, the categorical predictions are all correct. The statistical deviance in (3ab) is again potentially due to the coarse grain of the model.

(55) Predictions and observed frequencies: 5-syllabic stems

	Motif	Pred. %	Obs. %	Examples
1a	L.TÁA	100	100 (101)	á.jat.te.li.jòi.den
1b	L.TA	0	0 (0)	–
2a	L.TÓO	100	100 (41)	té.le.vi.si.òi.den
2b	L.TO	0	0 (0)	–
3a	L.TÍI	33	11.8 (2)	Á.lek.sàn.te.rèi.den
3b	L.TI	67	88.2 (15)	Á.lek.sàn.te.ri.en
4a	L.H.TÁA	0	0 (0)	–
4b	L.H.TA	100	100 (2)	é.van.ke.lìs.to.jen
4c	H.H.TÁA	50	– (0)	–
4d	H.H.TA	50	– (0)	–
5a	L.H.TÓO	0	0 (0)	–
5b	L.H.TO	100	100 (1)	í.ta.li.àa.no.jen
5c	H.H.TÓO	20	20% (2)	kóor.di.nàa.tis.tòi.den
5d	H.H.TO	80	80% (8)	kóor.di.nàa.tis.to.jen
6a	L.H.TÍI	0	0 (0)	–
6b	L.H.TI	100	100 (99)	só.si.a.lìs.ti.en
6c	H.H.TÍI	0	0	–
6d	H.H.TI	100	100 (2)	á.vant.gàr.dis.ti.en

With 5-syllabic stems we are clearly running out of corpus. The model however keeps making quantitative predictions, such as 50%/50% for (4cd), claiming that if a word of this type existed it would permit both variants to an equal degree. This prediction is in principle testable by means of nonsense examples. This is something a generative model of variation can accomplish: the predictions go beyond the corpus reflecting the variation competence of Finnish speakers.

6 Conclusion

In the beginning of this paper, we recognized three distinct aspects of the variation problem. We now conclude by summarizing the proposed answers.

(56) The locus of variation: Why does variation occur where it occurs? In the case of Finnish, why only in long words of a certain prosodic shape?

On our account, variation emerges in environments where the grammar underdetermines the output. Finnish stress is an instructive example. In short words weight is subject to obligatory initial stress. Variation springs from the fact that the grammar is silent about the location of secondary stress – something that is only relevant in long words – thus potentially allowing multiple alternatives. Quantitative predictions are another case where variation arises from lack of information: here partial ranking fails to reduce the output to one single candidate, the result being an array of disagreeing tableaux and multiple winners. Again, this gradient effect only emerges in long words which are indifferent to the dominating stress considerations.

(57) Degrees of variation: Why is one variant preferred over the other? How can grammars predict gradient intuitions?

The present model makes the relationship between categorical phenomena and variation explicit: a categorical phenomenon is the limiting case where all the tableaux happen to converge on a single winner. Preferences arise if the partial order is too weak to select a unique winner, but strong enough to leave its statistical fingerprint on the output. As a result, one candidate beats another only quantitatively, by winning in a greater number of tableaux. This gives us a simple and straightforward way to express gradient intuitions by discrete means. Under our analysis, the difference between categorical phenomena and variation is literally quantitative, not qualitative. Both result from constraint interaction within one and the same grammar.

(58) Stability: Why has this fluctuation lasted for centuries without levelling out?

As Liberman (1994) points out, the available theories do not offer a satisfactory answer to the question why some cases of variation linger for centuries without very much change, while others move (quickly or slowly) towards a categorical resolution. The Finnish case is clearly of the former type. One speculative answer suggests itself within the present model: if variation is due to partial ranking, then eliminating it would mean complicating the grammar by adding rankings, instead of simplifying it. There would thus be no system-internal reasons for doing away with variation. The same explanation would not be available for variation due to allomorphy (distinct underlying forms).

Finally, the present study underlines the methodological importance of large on-line corpora. While grammaticality judgments are usually sufficient when one deals with categorical phenomena, this is not the case in variation studies. Grammatical intuitions give useful hints in identifying the relevant factors, but they turn out unstable especially if the variants are very close to each other in optimality. However, while a single intuition may be unreliable, 10,000 intuitions are much less so, and while it is perhaps impractical to elicit 10,000 intuitions from the same speaker in a short period of time, a large on-line corpus is a good surrogate informant.

Notes

[1]Preliminary versions of parts of this paper were presented at the 23rd Conference on New Ways of Analyzing Variation (Stanford University, October 1994), the Stanford Phonology Workshop (March 1995) and the 4th Trilateral Phonology Workshop (UC Santa Cruz, May 1995). I am grateful to the participants of these meetings for helpful questions. I wish to thank Paul Kiparsky, Chris Culy, Vivienne Fong, Fred Karlsson, Brett Kessler, Will Leben, Rob Malouf, Ruben van de Vijver and Tom Wasow for their valuable comments and contributions. Special

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[2]Many morphophonological intricacies will have to be suppressed to keep this paper to manageable length. Both strong and weak forms have several phonologically distinct realizations: *-iden, -itten, -ten* (strong forms) and *-en, -jen* (weak forms). I will not discuss the respective phonological derivations here, but see Karlsson (1982) and Keyser and Kiparsky (1984). Paunonen (1974) provides the diachronic and dialectal background. The present discussion is limited to the alternation between the strong and weak classes; I will not address the more specific question of which allomorph within each class is chosen in which environment. Here the reader is referred to Anttila (forthcoming). Finally, the stem-final vowel alternation $a \sim o$ and $i \sim e$ is triggered by the presence of a following *i, j*. As this does not bear on the main point of this paper, it will be ignored.

[3]Note the following caveats: (i) I am assuming that the irregular root type *vesi* 'water' has two root variants: /vet/ (monosyllabic) and /vesi/ (disyllabic) which give rise to two inflectional variants: *vét.ten* and *vé.si.en*. The same applies to *ydin* 'core' which has both a disyllabic and a trisyllabic allomorph (/ydin/, /ytime/; *ý.din.ten*, *ý.ti.mi.en*); (ii) The claim that Finnish has no CV-roots ignores pronouns, such as *ne* 'they' (*níi.den*) which is counted among CVV-finals here, the coordinating conjunction *ja* and the adverb *jo* 'already'. The latter are not inflected and are thus irrelevant; (iii) The relative pronoun *joka* (*jói.den*) is assumed to have the monosyllabic stem /jo/ (Hakulinen 1961, 71).

[4]The stem-final vowels undergo morphophonological alternation: /a/ = $a \sim o$, /i/ = $i \sim e$ while /o/ does not alternate. For sonority purposes, the underlying form is all that counts. Thus, the *o*-alternant counts as /a/ ([+low]), the *e*-alternant counts as /i/ ([+high]).

[5]Note the following caveats: (i) There is a class of A-final roots which delete the vowel and assume the weak variant categorically. Examples: /neuvoja/ 'consult' *neu.vo.ji.en*, /ajava/ 'driving' *a.ja.vi.en*, /ohjelma/ 'program' *oh.jel.mi.en*, /ankeimpa/ 'sad' *an.keim.pi.en*, /antama/ 'given' *an.ta.mi.en*, /emäntä/ 'matron' *e.män.ti.en*. More than phonology is involved here: consider stems like /avara/ 'broad' which deletes /a/ and /tavara/ 'belonging' which does not. This idiosyncratic morphological constraint partially masks general phonological factors and is better discussed separately; (ii) The apparently trisyllabic type /makea/ 'sweet' *ma.kei.den* is excluded. These roots are really disyllabic –CVV-finals by a number of phonological criteria, including inflection; (iii) Roots ending in a "weak" /-e/ which always deletes (e.g. *pituuksien, muutoksien*, underlyingly perhaps /pituukse/, /muutokse/, see Keyser and Kiparsky (1984)) are not discussed here.

[6]The adjacent weight effect is easiest to observe with O-final stems. With A-finals and I-finals it is partially masked by the strong sonority effect.

[7]Note how this situation differs from the one shown in (18). In a tie, the competition continues and constraints ranked below A, B and C are potentially active on this set. In (20) and (21) the competition terminates: there are two totally ranked tableaux; each predicts a single winner which happen to be distinct. Consequently, constraints below A, B and C are totally irrelevant.

[8]We shall later propose that UG provides some rudimentary initial ranking which is subsequently elaborated on by language learners.

[9]Phonetically, the correlates of the three categories overlap: stress is reflected in duration, vowel quality, loudness and pitch; weight is typically realized as duration; sonority corresponds

to vowel quality, loudness and pitch (Ladefoged 1993, 243-257). As for phonology, in many languages rules of stress assignment refer to weight (Hayes 1995) and to sonority (Kenstowicz 1994).

[10]For the moment, I am working with the idealization that there are only two levels of stress: stressed vs. unstressed.

[11]For a discussion of *H.H, see Zoll (1992).

[12]In terms of Tesar and Smolensky (1995, 129), the grammar in (31) is a Stratified (Domination) Hierarchy.

[13]The question why stems that underlyingly end in a heavy syllable, such as *palt.too* 'coat' and *va.ras* 'thief', exlusively take strong variants is not explained by this ranking. The problem is left for future work.

[14]For more arguments, see Keyser and Kiparsky (1984).

[15]In fact, our analysis predicts that both the presence/absence of variation and the choice between strong/weak is potentially sensitive to syllables arbitrarily far left. This unboundedness is however epiphenomenal; it reduces to the three local constraints discussed here.

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