Variation in Finnish phonology and morphology

By Arto Anttila
Reviewed by Paul Boersma

Summary by the author

Variation, preferences, and subregularities can be derived from one and the same grammar if we assume that grammars are **partial orderings** of violable constraints. This is the claim defended in this dissertation. The argument is based on detailed analyses of the Finnish nominal declension.

1. Free variation

The Finnish genitive plural has multiple phonological realizations, here called **strong** and **weak** variants (Anttila, 1997). The variants are sometimes in complementary distribution, sometimes in free variation. The problem is to explain their distribution. Consider CV-final stems:

(1)

	STRONG	WEAK	
a. /lasi/	(*lá.sei.den)	lá.si.en	'glass'
b. /paperi/	pá.pe.rèi.den	pá.pe.rì.en	'paper'
c. /ministeri/	mí.nis.te.rèi.den	mí.nis.tè.ri.en	'minister'
d. /margariini/	(*már.ga.rìi.nei.den)	már.ga.rìi.ni.en	'margarine'
e. /aleksanteri/	á.lek.sàn.te.rèi.den	á.lek.sàn.te.rì.en	'Alexander'
f. /sosialisti/	(*só.si.a.lìs.tei.den)	só.si.a.lìs.ti.en	'socialist'

In (1a), (1d) and (1f) the weak variant is obligatory; in (1b), (1c) and (1e) either variant is possible. No lexical conditioning is involved. The key observation is that the strong variant creates a heavy penult, while the weak variant creates a light penult. This weight difference interacts with word prosody in ways that make the choice completely predictable from stress.

The core generalizations concerning Finnish stress are as follows (Sadeniemi, 1949; Carlson, 1978): (a) Primary stress falls on the initial syllable; (b) Secondary stress falls on every second syllable after the initial one, skipping a light syllable if the syllable after that is heavy, unless that heavy syllable is final; (c) Adjacent syllables within a word are never stressed. In addition, final syllables may be optionally stressed if heavy, subject to (a)–(c). Assuming the idealization that final syllables are never stressed (but see Anttila & Cho, 1998), the distribution of the variants in CV-final stems is simple to state:

(2) The strong and weak variants are in free variation, except if the penult must remain unstressed, in which case only the weak variant is possible.

A closer examination of the variable cases reveals that the variants are hardly ever on an equal footing. Typically, one sounds better than the other although both are possible. Which variant is preferred depends on the stem. Instead of eliciting native speaker judgements regarding the relative well-formedness of each variant in combination with thousands of stems, I used an electronic corpus containing all the 1987 issues of *Suomen Kuvalehti*, a Finnish weekly magazine (1.3 million words, 28 000 genitive plurals) made available via the University of Helsinki Language Corpus Server.

(3) TOKEN FREQUENCIES IN SOME TRISYLLABIC STEM TYPES

STEM	STRONG	WEAK	
a. /ka.me.ra/	ka.me.roi.den (99.4%)	?ka.me.ro.jen (0.6%)	'camera'
b. /sai.raa.la/	sai.raa.loi.den (50.5%)	sai.raa.lo.jen (49.5%)	'hospital'
c. /pa.pe.ri/	pa.pe.rei.den (37.2%)	pa.pe.ri.en (62.8%)	'paper'
d. /po.lii.si/	?po.lii.sei.den (1.4%)	po.lii.si.en (98.6%)	'police'

Two generalizations emerge: (a) Stems ending in a low vowel prefer the strong variant; stems ending in a high vowel prefer the weak variant (the alternations *a~o* and *i~e* are triggered by the following plural (*i*); (b) Stems with a heavy penult prefer the weak variant; stems with a light penult prefer the strong variant (Itkonen, 1979).

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In sum, phonology influences the distribution of the strong and weak variants in two ways: (a) Stress determines whether variation is possible or not; this regularity is categorical; (b) In the variable cases, vowel height and adjacent syllable weight determine the relative well-formedness of the variants; this regularity is quantitative. The problem is how to account for both kinds of facts in the same grammar.

The categorical facts can be captured by four ranked constraints. I assume that INITIAL STRESS and *FINAL STRESS are undominated, and *Ý.Ý ''Adjacent stressed syllables are bad'' ranks above *H ''Unstressed heavy syllables are bad''.

(4)

/ministeri/'minister'		*Ý.Ý	*H
mí.nis.te.ri.en	☞ Í.H.L.L.H		**
mí.nis.tè.ri.en	☞ Í.H.Ì.L.H		**
mí.nis.te.rì.en	☞ Í.H.L.Ì.H		**
mí.nis.te.rèi.den	☞ Í.H.L.Ì.H		**
*mí.nis.tè.rei.den	Í.H.Ì.H.H		***!
*mí.nìs.te.ri.en	Í.Ì.H.L.H	*!	*
/margariini/'margarine'		*Ý.Ý	*H
már.ga.rìi.ni.en	☞ Í.H.Ì.H.H		*
*már.ga.rii.nì.en	Í.H.H.Ì.H		**!
*már.ga.rii.ni.en	Í.H.H.L.H		**!
*már.ga.rìi.nei.den	Í.H.Ì.H.H		**!
*már.ga.rii.nèi.den	Í.H.H.Ì.H		**!
*már.ga.rìi.nèi.den	Í.H.Ì.Ì.H	*!	*

This correctly predicts that /ministeri/ allows both variants (within the weak variant, three alternative stress patterns are predicted), whereas /margariini/ only allows the weak variant due to its heavy third syllable which attracts secondary stress.

The quantitative regularities are also phonology-induced. It thus seems that phonology should account for them. I derive the vowel height effect from the hypothesis that low vowels are preferred in heavy syllables, high vowels in light syllables. (For Finnish-specific phonetic evidence, see Wiik, 1965.) This is stated as two ranked constraint pairs: *H/I ≫ *H/A ''*tii* is worse than *taa*'' and *L/A ≫ *L/I ''*ta* is worse than *ti*''. The adjacent syllable weight effect is derived from *L.L ''No adjacent light syllables'' and *H.H ''No adjacent heavy syllables''. Since these six constraints only emerge in the variable cases, they must rank below the stress constraints. The problem is, of course, that the effects are only quantitative.

Suppose we simply leave the grammar as it stands:

(5) *Ý.Ý ≫ *H ≫ {*H/I ≫ *H/A, *L/A ≫ *L/I, *L.L, *H.H}

Grammar (5) is a partial order translatable into 180 tableaux. If we check the output of each tableau for the four stems, the following pattern emerges:

(6)

	/poliisi/	/paperi/	/sairaala/	/kamera/
18	**strong**	**strong**	**strong**	**strong**
24	weak	**strong**	**strong**	**strong**
12	weak	**strong**	weak	**strong**
66	weak	weak	**strong**	**strong**
6	weak	weak	weak	**strong**
54	weak	weak	weak	weak

The strong variant *pó.lii.sèi.den* wins in 18/180 = 10% of the tableaux; *ká.me.ròi.den* wins in 126/180 = 70% of the tableaux; *pá.pe.rèi.den* and *sái.raa.lòi.den* fall somewhere in between. Grammar (5) thus assigns each variant a number between 0 and 1 reflecting its optimality computed over the entire partial ordering. I propose the following interpretation:

(7) QUANTITATIVE INTERPRETATION

a. A candidate is predicted by the grammar iff it wins in some tableau contained within the partial ordering;

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

(8)

	s	w	s	w	s	w	s	w
Grammar:	10%	90%	30%	70%	60%	40%	70%	30%
Corpus:	1.4%	98.6%	37.2%	62.8%	50.5%	49.5%	99.4%	0.6%
	/poliisi/		/paperi/		/sairaala/		/kamera/	

The quantitative fit can be improved by additional rankings. However, even with this maximally simple system, with no Finnish-specific rankings to fine-tune the numbers, we obtain a rough approximation of the quantitative facts.

2. Subregularities

Finnish has two phonological rules that affect stem-final low vowels. These rules are virtually exceptionless in nonderived stems with an even number of syllables.

(9)

a → Ø/u,o __ + i	Vowel deletion after rounded vowels.
a → o/i,a,e __ + i	Vowel mutation after unrounded vowels.

(10)

/muna/	mun-i-ssa	*muno-i-ssa	'egg-PL-INE'
/synagooga/	synagoog-i-ssa	*synagoogo-i-ssa	'synagogue-PL-INE'
/kana/	*kan-i-ssa	kano-i-ssa	'hen-PL-INE'
/balleriina/	*balleriin-i-ssa	balleriino-i-ssa	'ballerina-PL-INE'

Trisyllabic stems show weak reflexes of (9): (a) *a~o* is strongly dispreferred after /o/ because of the dissimilatory bias against the *o.o* sequence: /miljoona/ 'million' *miljoon-i-ssa* (**miljoono-i-ssa*); (b) a~Ø is virtually banned after /i/ because of the dissimilatory bias against the *i.i* sequence: /masiina/ 'machine' *masiino-i-ssa* (**masiin-i-ssa*). In the absence of phonological pressure either way, the result may be variation: /kastanja/ 'chestnut' *kastanj-i-ssa~kastanjo-i-ssa*. A partial ordering analysis based on roundness and height dissimilation is readily available. However, (11a) reveals an additional morphological condition on variation: nouns typically mutate, adjectives typically delete (Karlsson, 1978). The noun /jumala/ 'God' (11b) is a lexical exception.

(11)

	STEM	DELETION	MUTATION	GLOSS
a.	/tavara/$_n$	*tavar-i-ssa	tavaro-i-ssa	'belonging-PL-INE'
	/avara/$_a$	avar-i-ssa	*avaro-i-ssa	'spacious-PL-INE'
b.	/jumala/$_n$	jumal-i-ssa	*jumalo-i-ssa	'God-PL-INE'

Morphological and lexical conditions only emerge where the phonological conditions are weak or absent: the noun /glaukooma/ 'glaucoma' undergoes deletion (*glaukoom-i-ssa*) because of the penult /oo/. This suggests another interpretation of partial ordering:

(12) SUBREGULARITY INTERPRETATION
Morphological categories and lexical items may subscribe to a special phonology (a specific partial order) within the limits of the general phonology (a general partial order).

3. Conclusion

The generalization from total orderings (tableaux) to partial orderings is a natural move in Optimality Theory. As a result, both invariant/categorical and variable/quantitative regularities can be derived from the same grammar. Interesting formal relations between grammars emerge as well. In particular, grammars may include other grammars, which is the essence of the notion 'subregularity'.

Review by Paul Boersma

In this insightful account of Finnish variation data, Arto Anttila convincingly shows that obligatory and variable phonological phenomena can be expressed by a single grammar. Whether such a grammar should have the form that he proposes, namely a PARTIAL ORDER, is a different question. Fortunately, the explicit and detailed presentation allows the reader to replicate Anttila's findings and numbers, which helps us in trying to answer this question.

1. What kind of variation is being modelled?

Anttila uses a written corpus, which shows variation between forms. In general, such variation could be due to variation between lexical forms, to regional, stylistic, or pragmatic factors, to register, to random differences between speakers, and to random variations within speakers. Only in the last case would it be appropriate to regard the corpus variation as generated by a single grammar. The following quote shows why Anttila thinks that variation within the corpus does reflect random variation within speakers:

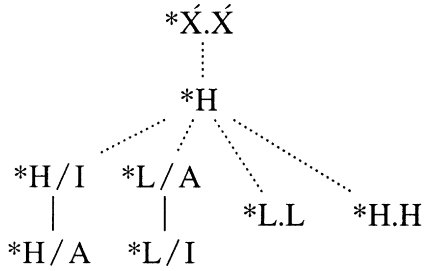
> Native speakers usually report that one variant sounds better than the other while agreeing that both variants are possible. These intuitions are independently confirmed by large corpora where the preferred variant is usually the more frequent one (p. 12).

To justify the modelling of corpus frequencies as the result of a single grammar, then, we will have to assume that all speakers share the same grammar, and that the speaker's grammaticality judgements reflect her own production probabilities. With this subject out of the way, I will concentrate on the farther-reaching issues, namely the comparison with other grammar models on points like psychological reality and learnability, which Anttila claims works out to the advantage of his model (pp. 23–29).

2. Anttila's grammar model: partial ordering

Anttila writes his grammars as a kind of strata of subhierarchies, as in (5) in the Summary. However, the class of partially ordered constraint grammars defined in his book by the properties of ''irreflexivity, asymmetry, and transitivity'' (p. 5) is larger than what can be represented by strata of subhierarchies. The actual class is equal to the class of grammars that can be depicted graphically as a dominance hierarchy, so I will graphically represent them as such (the difference will appear crucial below in §4.3). Thus, ranking (5) of the Summary can be depicted as

(1)



In this figure, dotted lines represent language-specific rankings, whereas solid lines represent rankings that Anttila considers universal. We see that *X́.X́ dominates *H, and *H dominates *L.L, so that by transitivity *X́.X́ dominates *L.L. The difference with standard Optimality Theory, however, is that not all rankings have to be specified. Thus, Figure (1) does not specify whether *L.L is ranked above *H/I, or between *H/I and *H/A, or below *H/A. This situation may lead to variation in the output for forms in which *L.L conflicts with *H/I. For instance, the form *pa.pe.ri.en* violates *L.L (*pe.ri*), and *pa.pe.rei.den* violates *H/I (*rei*), so according to (1) both outcomes are possible.

The **quantitative interpretation** of this variation, according to (7) in the Summary, is as follows. If we consider only the ranking of *L.L with respect to *H/I and *H/A, we see that out of the three possible total rankings only one (namely *L.L ≫ *H/I ≫ *H/A) favours the form *pa.pe.rei.den*. We expect, then, the form *pa.pe.rei.den* to occur in one third of the cases, and *pa.pe.ri.en* in two thirds. Adding the influences of *L/I (violated in *ri*) and *H.H (violated in *rei.den*) changes these numbers to 30 and 70%, respectively, as shown in (8) in the Summary.

Before touching upon the merits of the general class of partial orderings, I will discuss the simpler subclass of **stratifiable partial orderings**, which Anttila uses so successfully in chapter 2.

3. Stratifiable partial orderings

3.1. Stratified grammars

The actual grammar that Anttila uses to account for the Finnish *-jen/–iden* choice in genitive plurals, is different from the simplified grammar (1), and this difference will be crucial in my discussion. The actual grammar can be described as seven strata (internally unranked sets) of constraints:

(2)

Stratum 1 (undominated): *X́.X́ (plus InitialStress and NoFinalStress)

Stratum 2 (dominated only by the constraints of stratum 1): *Ĺ, *H

Stratum 3 (dominated by the constraints in strata 1 and 2): *H/I, *Í, *L.L

Stratum 4: *H/O, *Ó, *L/A, *H.H, *Ĥ, *X.X

Stratum 5: *H/A, *Á, *L/O, *A, *L

Stratum 6: *L/I, *O

Stratum 7: *I

In this hierarchy, *Ĺ ≫ *Ĥ militate against stressed light and heavy syllables, *H ≫ *L against unstressed heavy and light syllables, *Í ≫ *Ó ≫ *Á against stressed underlyingly high, mid, and low vowels, *A ≫ *O ≫ *I against unstressed low, mid, and high vowels, and *X.X against adjacent unstressed syllables.

The variable output of grammar (2) can be drawn in a single traditional Optimality-Theoretic tableau, with dotted lines dividing the contraints that are ranked at the same height. Example (3c) in the Summary would become (only three strata are shown):

(3)

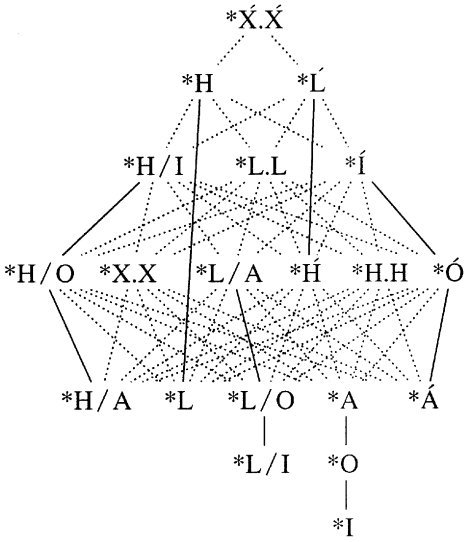
	2nd stratum		3rd stratum			4th stratum					
paperi-GenPl	*Ĺ	*H	*H/I	*Í	*L.L	*H/O	*Ó	*L/A	*H.H	*Ĥ	*X.X
☞ pá.pe.rèi.den	*	*	*	*		*		*	*	*	
☞ pá.pe.ri.en	*	*			*	*		*			**

There are two winners; which of them wins at evaluation time (i.e. every time a surface form has to be produced), is determined by the coincidental order of the constraints in the third stratum, which will randomly vary between evaluations (none of the constraints in the second stratum has any preference for either form). The form *pá.pe.rèi.den* will win in

one third of all cases, namely whenever *L.L happens to be on top of the third stratum, and *pá.pe.ri.en* will win in two thirds, namely when *H/I or *Í is on top. In a stratified grammar therefore determining the production probabilities simply reduces to counting the preferences of the constraints, so that the probabilities will be rational numbers (fractions). Since the decision is made at the level of the third stratum, the cells in the fourth and lower strata can be greyed out, because the violations in these cells can never contribute to determining the winner.

At least, that is the **variation interpretation of** tied constraints, which was also defended by Pesetsky (1998, 372): ''The output of a set of tied constraints is the union of the outputs of every possible ranking of those constraints''. In the traditional interpretation of the tie, however (Tesar & Smolensky, 1998, 241), the violations of all the constraints in a stratum are added up, so *paperien* would be the winner because it has only one violation mark in the third stratum, whereas *papereiden* has two.

(4)



(4a) strata as partial order

120 *X́.X́

110 *H *Ĺ

100 *H/I *Í *L.L

90 *H/O *Ó *L/A *H.H *Ĥ *X.X

80 *H/A *Á *L/O *A *L

70 *L/I *O

60 *I

(4b) strata as continuous ranking

3.2. Constraint set

Anttila's large constraint set may arouse the suspicion that several constraints have been included solely for the purpose of probability matching.

The most controversial seem the constraints that express the anticorrelation between weight and vowel height. If *H/I were left out of the grammar, that would shift *papereiden/paperien* to a 50–50 distribution. Other than for fixing up this ratio in the direction of the attested 2-to-1 distribution, we must believe that Anttila included the weight/height constraints on the basis of observed cross-linguistic tendencies, like the ubiquitous shortening of high vowels. As Anttila convincingly argues in all of his three case studies, the weight/height constraints are at the very basis of many phenomena in Finnish.

Another example is the inclusion of several somewhat perverse sounding constraints like *Ĥ ''no stressed heavy syllables'' and *Á ''no stressed low vowels''. Including *Ĥ certainly looks innocent, since it is always dominated by *Ĺ. However, *Ĥ crucially comes to support *H.H in making *sáiraalòiden* as bad as *sáiraalojen*, so this perverse constraint does make its influence felt in the output probabilities. The inclusion of these constraints is like expressing Prince & Smolensky's (1993) syllable type preferences as the fixed rankings ONSET ≫ NOONSET and NOCODA ≫ CODA. This move is certainly a principled and defensible decision: no logically possible constraint is excluded beforehand, and considerations of articulation or perception will predict a cross-linguistically fixed ranking.

3.3. Two more powerful grammar models

Stratified grammars can be described as special cases of partial orders. Grammar (2), for instance, can be represented graphically as in Figure (4a) (only the top five strata are shown completely).

However, stratified grammars can also be described as special cases of continuously ranking grammars with noisy evaluation. In such a grammar (Boersma, 1997, 1998, chs. 14–15; Zubritskaya, 1997, 143), every constraint has a ranking value along a continuous scale, and at evaluation time a random value (drawn from a Gaussian distribution) is temporarily added to the ranking of each constraint, so that the actual ranking values that are used for determining the winner vary from one output production to the next. Such a grammar can be considered **stratified** if all constraint pairs are ranked either at approximately equal height (causing variation with fractional probabilities) or at very different heights (causing categorical, nonvariable, behaviour); Figure (4b) shows instances of both of these cases.

Both grammar models (partial order and continuous ranking) are more powerful than the simple stratified grammars. There exist genuine partial orders, like (1), that cannot be represented as continuous rankings, and there exist genuine continuous rankings that cannot be represented as partial orders. It can thus be empirically determined which of the three grammar models is the correct way to describe variation. Since the most restrictive model (stratified grammars) works fine for Anttila's first example, this model must be our working hypothesis until evidence to the contrary arrives.

3.4. Learnability of stratified grammars

An important aspect of the stratifiability of a partial constraint ordering lies in its learnability. Whereas no nonexponential learning algorithm has yet been devised for the general problem of partial orders, we are sure that a stratified variation grammar can be learned, because it is a special case of a continuously ranking grammar.

The learning algorithm associated with continuously ranking grammars is quite simple (Boersma, 1997, 1998, ch. 15). The learner will repeatedly compare her own output forms with adult forms. If her own form is different from the adult's, she will change her grammar by moving all the constraints that prefer her own form up along the continuous ranking scale (by a small step), and by moving all the constraints that prefer the adult form down along that scale. In this way, the grammar will gradually become more likely to produce adultlike forms.

When applied to the Finnish genitive plurals, this algorithm shifts the 19 constraints, which are initially ranked at the same height, to positions that are quite different from the stratification (2), though X́.X́ $\gg$ *H will still be ranked categorically on top; the output distribution derived from this grammar matches the observed data a little bit better than (2) does, as must be expected on the basis of the added power. If the constraint set is reduced to 13 constraints (by removing the two height/weight hierarchies plus *Ĥ and *L), the algorithm still manages to obtain a probability match comparable to the one of (2) (Boersma & Hayes, 1999).

3.5. What stratification tells us about the likely powerful grammar model

There is nothing in partial orders that favours stratification. Grammar (4a) does not look like a genuine partial order like (1); rather, it looks like a genuine stratified hierarchy quite artificially forced into the straitjacket of partial ordering. The same, of course, can be said about the artificial continuous ranking in (4b), which looks rather discrete. However, we can show that under certain conditions, the gradual learning algorithm tends to cause constraints to gang up into strata.

If there are lots of evidence for the rankings A $\gg$ B and A $\gg$ C, as well as lots of evidence for the rankings B $\gg$ D and C $\gg$ D, the algorithm will draw the constraints from one another until A is ranked well above B and C, and D is ranked well below B and C. If the starting point for the learning algorithm is that all the constraints are ranked at the same height, and B and C are never in conflict, it is quite probable that B and C will end up at approximately the same height, so we will probably arrive at the stratified ranking A $\gg$ { B, C } $\gg$ D. Now if B and C are conflicting, but only very rarely so, it will take the learner quite a long time to draw apart the rankings of B and C. Thus, B and C will stay in each other's vicinity for quite a long time, and young learners meet many older children whose B and C constraints are not yet categorically ranked in the adult way. Therefore, the average language environment will, in the case of B and C, contain a lot of variation even if the adult grammar is categorical. This will cause the young learner to acquire the adult ranking of B and C even slower than in the case of a categorical language environment. This again leads to more variation, and the categorical B–C ranking will be lost from the speech community within a few generations. This means that if two constraints are rarely in conflict, languages will often tend to rank them at the same height, so that fractional variation probabilites will arise. In the Finnish case, the relevant constraints conflict only in the case of morphological optionalities, so the condition of relatively rare conflict (as compared with the constraints that determine stress patterns) has been fulfilled.

Within the continuous-ranking model, stratification is expected; within the partial-order model, it is not.

3.6. Partial vs. total orders

Anttila maintains that a totally ranked grammar 'is the most complex case and presupposes the greatest amount of learning' (p. 29). I want to challenge this, because simplicity depends on your view of the grammar.

In assessing simplicity, Anttila counts the number of ranked pairs. If the grammar is a set of ranked constraint pairs, then partially ordered grammars are simpler than totally ordered grammars. For instance, Anttila's grammar (4a) needs only 56 immediately ranked pairs in the top five strata (including five universal rankings), plus 51 by transitivity. A totally ordered grammar with the same 17 constraints would involve $1/2 \cdot 17 \cdot 16 = 136$ ranked pairs, indeed a whole 29 more. An unranked grammar (all constraints in a single stratum), is the simplest grammar, and grammars get more complicated as the number of strata grows.

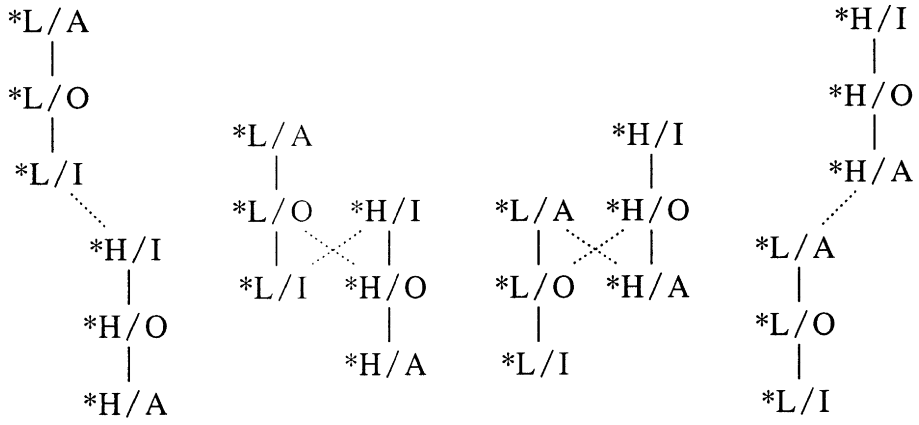
However, if a grammar is seen not as a list of ranked pairs, but instead as a set of constraints with their properties, a stratified grammar with 17 constraints would need only 17 stratum numbers (one for each constraint), whereas a partially ordered grammar would have to associate a list of dominators with each constraint (e.g. *L/O is ranked below 12 others). Counted in this way, stratified grammars are actually simpler than partial orders.

Moreover, general partial orders need complicated machinery to maintain the transitivity property during learning. Thus, since the hierarchy contains the ranking pairs *L/A ≫ *L.L and *L.L ≫ *H, the ranking pair *H ≫ *L/A should be excluded from consideration, which is not a trivial matter. In a grammar in which each constraint is associated with a stratum number (or with a continuous ranking value, for that matter), such transitivity falls out naturally.

4. Non-stratifiable Anttila grammars

In chapter 3, Anttila gives an account of language change. He adheres to a weak theory of language change, which cannot predict its direction, and according to which the historical stages only have to be typologically predicted systems, i.e. systems that preserve universal rankings such as *H/I ≫ *H/O ≫ *H/A.

(5)



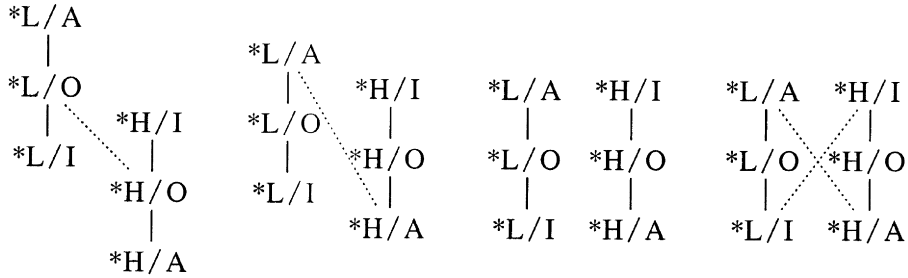
A (1 tab.)	B (9 tab.)	C (9 tab.)	D (1 tab.)
lin.tuin	lin.tu.jen	lin.tu.jen	lin.tu.jen
pel.toin	pel.toin	pel.to.jen	pel.to.jen
ak.kain	ak.kain	ak.kain	ak.ko.jen

4.1. The change

The shift has probably started with an independent sound change, namely the loss of the dental fricative /ð/. Before this change, the genitive plural of /akka/ 'woman' was variably /akkaðen/ (short) or /akkoiðen/ (long). After the change, the forms became *ak.kain* (short) and *ak.ko.jen* (long). The first of these has a superheavy final syllable, and it may have been this ''problem'' that caused a subsequent shift in preference from the short forms to the long forms, starting with the high vowels (*lintu* 'bird'), and proceeding through the mid vowels (*pelto* 'field') to the low vowels (*akka*). Anttila distinguishes the short and long forms on the basis of his familiar height/weight constraints: *ak.kain* violates *H/A (*kain*), whereas *ak.ko.jen* violates *L/A (*ko*). Note that Anttila does not count the *H/O violation in the last syllable of *ak.ko.jen*, which he dispenses with by calling the vowel *e* 'synchronically epenthetic' (p. 64, fn. 4). With these constraints, four nonvarying grammars are possible:

Note that including the lowest-ranked of any hierarchy (*H/A, *L/I) is crucial; otherwise, we would never find *lintuin* or *akkojen*. The typology ranges from all-heavy (A) to all-light (D), with intermediate grammars in which low vowels love heavy syllables and high vowels love light syllables (B and C). Several variation grammars arise from combining grammars adjacent in (5):

(6)



AB	ABC	ABCD	BC
lin.tuin 1/10	lin.tuin 1/19	lin.tuin 1/20	lin.tuin 0/18
pel.toin 10/10	pel.toin 10/19	pel.toin 10/20	pel.toin 9/18
ak.kain 10/10	ak.kain 19/19	ak.kain 19/20	ak.kain 18/18

The grammars BCD and CD, not in this figure, are mirror images of ABC and AB.

The well-attested grammars from the 16th century on are more or less in chronological order: AB, ABC, ABCD, BCD, CD, D. The intermediate grammars B, C, and BC do not seem to occur; they are exactly the ones with a categorical difference between high and low vowels.

4.2. Why the data point to a single variation grammar

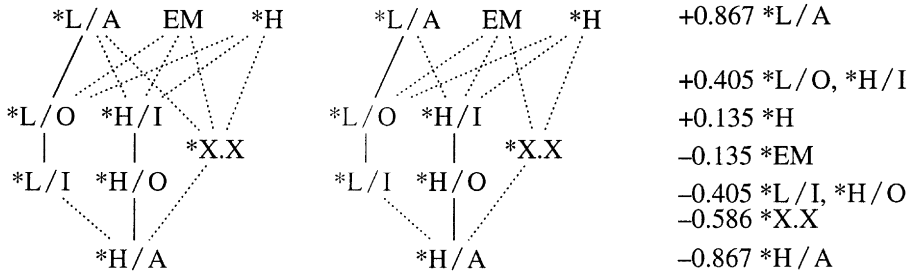
Anttila interprets these results as an argument against a multiple-grammar model. He predicts that grammars like AC and AD, which a multiple-grammar model would allow, are impossible because we cannot regard them as partial orders. And indeed, AD is not attested: no dialect has short and long forms with equal probabilities for high and low vowels; as we see from (6), any possible grammar with variation for all vowel heights must be ABCD, and this grammar will have 5% short forms for high vowels, 50% for mid vowels, and 95% for low vowels.

This interpretation is Anttila's central thesis. It still leaves room for each of our three grammar models. However, (6AB) and (6ABC) cannot be represented as stratified grammars, so this leaves partial orders and continuous rankings as the remaining candidates for the modelling of variation in a single grammar.

4.3. Modelling Lönnrot's Finnish

Anttila derives a reasonable probability matching for a 19th-century ABCD-like corpus (the writings of Elias Lönnrot) by adding two old friends to the constraint set: *H (no unstressed heavies) and EM (for ExtraMetricality: no final stresses). Anttila's best match is grammar (7a), a genuine partial order, which is not a completely stratified grammar, but can still be represented in Anttila's format, namely as three strata with two subhierarchies in the second stratum.

(7)



(7a) Anttila's match 5.3% (7b) improved match 4.6% (7c) GLA match 3.2%

The output distribution generated by (7a), which is shown in Table (8), matches the observed distribution by a mean absolute error of 5.3%. In a footnote, Anttila states that ''it is possible that an even better one exists''. Indeed, if we sever the dominance of *L/A over *X.X, as in (7b), the predictions improve: the mean absolute error drops to 4.6%. Grammar (7b), though a genuine partial order, is no longer representable as strata with subhierarchies, which may be the cause why Anttila missed it.

We see that small changes to a partial order yield small changes in the expected distribution. This shows that the matches of (7a) and (7b) are hardly evidence for the partial-order hypothesis: it looks as if partial orders sample the distribution space so densely that any distribution can be matched reasonably by a partial order.

Beside partial orders, continuous rankings can match the data well. Grammar (7c) is a continuous-ranking grammar that, with a noise standard deviation of 1.0 generates a distribution that is only 3.2% removed from the observed distribution. In general, of course, a set of nine continuously rankable constraints (i.e. eight degrees of freedom) is more powerful than a partial order that can generate only 10 080 tableaus, so this slightly better match had to be expected and is no direct evidence for the correctness of either grammar model.

4.4. Evidence for correctness

With a χ^2 test we can compute the probability that a specific proposed grammar model can give rise to a distribution at least as far away from the distribution derived by the proposed model, as the observed distribution is. With six degrees of freedom, as in (8), we expect χ^2 values around 6 if an a priori proposed distribution does underlie the observed data. If the χ^2 value is much smaller, as in the columns ''Anttila's match'' and ''improved match'', we must reject the hypothesis that the grammar model underlies the data; if the χ^2 value is much greater than 6, as in the column ''GLA match'', it becomes likely that the experimenter has matched the model with the data a posteriori.

We note that although Anttila tried a posterior fit of his model to the data, the χ^2 values are low, so that his specific grammar models must be rejected (which does not mean that they cannot be near the truth). Since model (7a) predicts 100% *akanain* forms, the form *akanojen* should not occur. Since this form does occur, the model can never underlie the observed data (χ^2 is infinite, $P = 0$). With the improved partial order (7b), χ^2 drops to a finite, though still high value, giving a probability of 3.5% for this improved model of yielding a distribution as

(8) MATCHING THE PROBABILITIES OF SHORT FORMS

Short ~ long	N	Observed short	Observed percentage	Anttila's match	Improved match	GLA match
Lin.tuin ~ lin.tu.jen	274	64	23.4%	20.0%	21.9%	22.5%
Pel.toin ~ pel.to.jen	145	78	53.8%	45.0%	45.3%	54.6%
Ak.kain ~ ak.ko.jen	305	213	69.8%	66.7%	65.6%	70.4%
En.ke.lein ~ en.ke.li.en	58	16	27.6%	25.0%	26.6%	31.1%
Va.li.oin ~ va.li.o.jen	15	12	80.0%	75.0%	73.4%	71.1%
a.ka.nain ~ a.ka.no.jen	56	51	91.1%	100.0%	96.9%	87.0%
Mean absolute error				5.3%	4.6%	3.2%
χ^2				∞	13.55	1.95
P (df = 6)				0	0.035	0.924

far away from the expected one as we observe. The continuous-ranking grammar (7c) fits the data especially well: χ^2 drops to such a low value, that the data are matched more accurately than they deserve ($P = 92.4\%$), which reveals the effects of doing a posterior fit.

Thus, the observed distribution is a likely outcome for a grammar in the vicinity of (7c), and an unlikely outcome for grammars (7a) and (7b).

5. Errors and other problems

I found few errors of analysis in Anttila's book. On page 73 (and 76), Anttila counts 99 *én.ke.lì.en* and 36 *én.ke.li.èn* tableaus; these numbers should be 81 and 54, respectively, but this does not influence the result.

In a footnote (p. 18) and an appendix (p. 143), Anttila explains the ungrammaticality of **kla.ri.ne.tei.den* (next to *kla.ri.net.ti.en*) on the basis of the presence of a short geminate *t*, which would make the third syllable heavy. Presumably, Anttila based this on the grammaticality of a prosodically comparable form like *jú.ni.o.rèi.den* (the only H.L.L.H.H form in Anttila's corpus of 7000 stem types of genitive plurals; occurs 4 times). However, *jú.ni.o.rèi.den* only has to compete with *jú.ni.o.ri.en* (occurs 3 times), which violates a stratum-3 constraint itself, whereas **klá.ri.ne.tèi.den* has to wage an unequal fight against *kla.ri.net.ti.en*, which is phonologically perfect. The forms **kla.ri.ne.ti.en* and **jú.ni.òr.ri.en* are put out of contest by an independent rule of Finnish according to which voiceless plosives, but not sonorants, are geminated between light non-initial syllables; we could tentatively describe this rule by sandwiching the already available structural constraint *L.L between two faithfulness constraints against gemination: *INSERT (length/sonorant) ≫ *INSERT (length/plosive). The tableaus for the two forms are:

(9)

juniori-GENPL	*INSERT (length/sonorant)	*H	*H/I	*Í	*L.L	*INSERT (length/plosive)
☞ jú.ni.o.ri.en		*			***	
jú.ni.òr.ri.en	*!	*			*	
☞ jú.ni.o.rèi.den		*	*	*	**	
jú.ni.òr.rei.den	*!	**	*		*	

(10)

Klarineti-GENPL	*INSERT (length/sonorant)	*H	*H/I	*Í	*L.L	*INSERT (length/plosive)
klá.ri.ne.ti.en		*			**!*	
☞ klá.ri.nèt.ti.en		*			*	*
klá.ri.ne.tèi.den		*	*	*	**!	
klá.ri.nèt.tei.den		**!	*		*	*

Since the correct output forms can be found by evaluating and comparing the surface candidates, the ungrammaticality of **klarineteiden* constitutes no evidence for an underlying geminate *t*. Rather, it provides some evidence for the idea that Anttila's constraint set plays a role not only in the choice between long and short endings, but also in the choice between geminated and ungeminated forms, an idea worth pursuing in the light of the interesting phonology of Finnish gemination.

Another possibly unwanted side-effect of the constraints for stress/height anticorrelation is that they predict a different secondary stress placement from the left-to-right rules in the Summary. This occurs in words with heavy third and fourth syllables, if the fourth syllable has a lower vowel than the third. Anttila's corpus contains a couple of these forms, among which *merkityksettömien*, where the constraint set predicts stress on *set* because its vowel is lower than the vowel in *tyk*. Interestingly, the judgements of native Finnish speakers seem to show variation on third-and-fourth-heavy words in general, which indicates that stress/height anticorrelation may play a role in stress assignment after all.

6. Conclusion

We have seen data that can be represented with stratified grammars (see (2), (3), (4), (9), (10)). For other data, we need a more powerful grammar model, which could be partial ordering (as in (1), (5), (6), (7a), (7b)) or continuous ranking (see (7c)). On the basis of what we discussed, we cannot determine which of these two models is correct, though with the present state of formal acquisition models, considerations of learnability and stratification tendencies seem to favour continuous ranking. To decide the issue, many more languages should be investigated, especially with the objective of finding empirical differences between the two models. The virtue of Anttila's exercise, in any case, is that it has showed us the existence and empirical adequacy of a theory that derives variation from a single grammar.

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