Workshop on Variation, Gradience and Frequency in Phonology
Stanford University, July 8, 2007

T-ORDERS AND LANGUAGE VARIATION

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(1) Overview:
- (a) Optimality Theory predicts typological generalizations (T-ORDERS)
- (b) These generalizations are reflected quantitatively in language variation
- (c) Empirical evidence from variable word stress in Finnish

1. Word Stress in Finnish

(2) Literature on Finnish word stress: Carlson 1978, Elenbaas 1999, Elenbaas and Kager 1999, Hanson and Kiparsky 1996, Karttunen 2006, Karvonen 2005, Keyser and Kiparsky 1984, Kiparsky 2003, Sadeniemi 1949.

(3) Primary stress is always initial. All the action is in secondary stress.

(4) The general pattern (binarity): Stress every other syllable after primary stress.

(a)	ká.las.tè.let	'you are fishing'
(b)	ká.las.tè.le.mì.nen	'fishing'
(c)	íl.moit.tàu.tu.mì.nen	'registering'
(d)	ú.jos.tè.le.màt.to.mùu.des.tàn.sa	'from his lack of shyness'

(5) The special pattern (ternarity): Skip a light syllable if the syllable after that is heavy unless the heavy syllable is final in which case skipping is optional.

(a)	ká.las.te.lèm.me	'we are fishing'
(b)	íl.moit.tàu.tu.mi.sès.ta	'from registering'
(c)	vói.mis.te.lùt.te.le.màs.ta	'from causing to do gymnastics'
(d)	rá.vin.tò.lat ~ rá.vin.to.làt	'restaurants'

(6) Analysis (first approximation): Binary trochaic feet from left to right; main stress on the leftmost foot; heavy syllables must be stressed.

(7) Problems:
- (a) Plenty of variation and apparent exceptions to the secondary stress rules.
- (b) Secondary stress is hard to hear or pin down by phonometric methods.

(8) Why is this important? Secondary stress plays a crucial role in the rest of Finnish phonology and morphology (Anttila 1997, 2002, Anttila and Cho 1998, Keyser and Kiparsky 1984, Kiparsky 2003, Ringen and Heinämäki 1999).

(9) In order to make progress, we need
  (a) A way of collecting stress intuitions from a large number of speakers.
  (b) A theory that can handle the variation and gradience evident in the data.

2. Methodology

(10) Proposal: Study secondary stress indirectly, through its segmental consequences.

(11) *t* → ∅ between unstressed light syllables (Keyser and Kiparsky 1984, Kiparsky 2003). Variable *t*-deletion reflects variable stress.

(a)	/maa-i-ta/	mái.ta	'country-PL-PAR'
(b)	/talo-i-ta/	tá.lo.ja	'house-PL-PAR'
(c)	/professori-i-ta/	pró.fes.sò.re.ja ~ pró.fes.so.rèi.ta	'professor-PL-PAR'

(12) *t*-deletion is a useful stress diagnostic because it is reflected in spelling.

(13) The method of collecting stress data:
  (a) Generate all the hypothetically possible partitive plural forms for all vowel-final nominal stems in an unabridged dictionary (Tuomi 1972, about 23,000 stems in all), http://www.ling.helsinki.fi/uhlcs/.
  (b) Use QueryGoogle to find matching words on Finnish web sites, http://www.linguistics.ucla.edu/people/hayes/QueryGoogle/
  (c) Result: 9.3 million partitive plural forms based on 10,000 different stems.

3. Empirical generalizations

(14) The key generalization: An extrametrical singleton *t* is deleted (cf. Anttila 2006)

(a)	/maa-i-ta/	(mái.ta)	'country-PL-PAR'
(b)	/talo-i-ta/	(tá.lo)ja	'house-PL-PAR'
(c)	/professori-i-ta/	(pró.fes.so)(rèi.ta) ~ (pró.fes)(sò.re)ja	'professor-PL-PAR'

3.1 Monosyllabic stems

(15) Monosyllabic stems show categorical *t*-retention.

(16)

(a)	*UNARY	No monosyllabic feet.
(b)	MAXφ	No deletion within a foot.
(c)	MAX	No deletion.
(d)	*T	No stops (**p, *t, *k*).

(17) Monosyllabic stems

/maa-i-ta/	*UNARY	MAXφ	MAX	*T
a. → (mái.ta)				*
b. (máa.ja)		*!	*	
c. (mái)ta	*!			*

3.2 Longer stems

(18) Generalization 1. The Weight-to-Stress Principle (WSP): Heavy syllables are stressed. This has two kinds of effects.

(19) Disyllabic stems: categorical *t*-deletion

/talo-i-ta/	...	WSP	MAX	*T
a. → (tá.lo)ja			*	
c. (tá.loi)ta		*!		*
d. (tá.loi.ta)		*!		*

(20) Longer stems: The skipping effect

(ád.re.na)(lìi.ne)ja 'adrenalin-PL-PAR' initial dactyl
(ál.le)(gò.ri.o)ja 'allegory-PL-PAR' initial trochee

/adrenaliini-i-ta/	…	WSP	MAX	*T
a. → (ád.re.na)(lìi.ne)ja			*	
b. (ád.re)(nà.lii.ne)ja		*!	*	
c. (ád.re)(nà.lii)(nèi.ta)		*!		*
d. (ád.re.na)(lìi.nei.ta)		*!		*
e. (ád.re.na)(lìi.nei)ta		*!		*
f. (ád.re)(nà.lii.nei)ta		*!*		*

(21) Generalization 2. CVV attracts stress from CVC (Karvonen 2005:81-94):

(kóor.di)(nàa.tis.to)ja CVV.CVC 'coordinate grid-PL-PAR'
(hó.ri.son)(tàa.le)ja CVC.CVV 'horizontal-PL-PAR'

(22) WSP/VV Heavy syllables with a long vowel are stressed.

/koordinaatisto-i-ta/	…	WSP/VV	WSP	MAX	*T
a.→ (kóor.di)(nàa.tis)(tòi.ta)			*		*
b.→ (kóor.di)(nàa.tis.to)ja			*	*	
c. (kóor.di.naa)(tìs.to)ja		*!	*	*	
/dialektiikka-i-ta/	…	WSP/VV	WSP	MAX	*T
a. (hó.ri)(sòn.taa)(lèi.ta)		*!	*		*
b. (hó.ri)(sòn.taa.le)ja		*!	*	*	
c. → (hó.ri.son)(tàa.le)ja			*	*	

(23) Stems longer than 2 syllables exhibit extensive variation. Different stems show very different quantitative profiles.

(24) Examples of variation. Three types of 4-syllable stems:

(a) (ál.ler.gi)(òi.ta) 99.7% ?(ál.ler)(gì.o)ja 0.3% 'allergy-PL-PAR'
(b) (pró.fes.so)(rèi.ta) 15.1% (pró.fes)(sò.re)ja 84.9% 'professor-PL-PAR'
(c) ?(fí.lo.so)(fèi.ta) 9.3% (fí.lo)(sò.fe)ja 90.7% 'philosopher-PL-PAR'

(25) Kiparsky (2003:113-4): Secondary stress is lexically fixed in some stems and variable in others. However, there remain subtle phonological conditions that govern the distribution of these fixed stresses.

(26) Generalization 3. The vowel sonority effect: /a, ä, o, ö/ are preferably stressed, /i, e, u, y/ are preferably unstressed (see also Kenstowicz 1994, de Lacy 2004, Crowhurst and Michael 2005). Morphophonemically {/a/, /o/} = /A/ and {/e/, /i/} = /I/.

(27) /allergia/ (X.H.I.A) 'allergy' vs. /professori/ (X.H.A.I) 'professor'

(a)	ál.ler.gi.òi.ta	99.7%	ál.ler.gì.o.ja	0.3%	X.H.I.A.X
(b)	pró.fes.so.rèi.ta	15.1%	pró.fes.sò.re.ja	84.9%	X.H.A.I.X

(28) Generalization 4. The prominence clash effect: Secondary stress avoids falling next to a heavy syllable (Inkelas 1999, 145).

(29) /professori/ (X.H.A.I) 'professor' vs. /filosofi/ (X.L.A.I) 'philosopher'

(a)	pró.fes.so.rèi.ta	15.1%	pró.fes.sò.re.ja	84.9%	X.H.A.I.X
(b)	fí.lo.so.fèi.ta	9.3%	fí.lo.sò.fe.ja	90.7%	X.L.A.I.X

(30) The constraints:

(a)	*x/A	No unstressed short A (= /a, ä, o, ö/)
(b)	*x/AA	No unstressed long A (= /a, ä, o, ö/)
(c)	*X/I	No stressed short I (= /e, i, u, y/)
(d)	*X/II	No stressed long I (= /e, i, u, y/)
(e)	*H.X	No stress next to a heavy syllable.

3.3 A morphological generalization

(31) Generalization: *t*-deletion only applies to suffixes, never to stems.

(32) PARSE-STEM Stems are exhaustively footed (undominated).
/traditio-i-ta/ → (trá.di.**t**i)(òi.ta) 'tradition-PL-PAR'

3.4 Other generalizations

(33) The following constraints are familiar from earlier work:

(a)	SWP	Stressed syllables are heavy.
(b)	FTBIN	Feet are disyllabic.
(c)	PARSE-σ	Syllables belong to feet.
(d)	ALL-FEET-LEFT	All feet are at the left edge of the prosodic word.

4. Analysis

(34) (a) Work out the predictions made by the above constraints.
(b) See how well they approximate the observed patterns in the corpus.

4.1 Three-syllable stems

(35) Possible 3-syllable stems (4 types): X.{L,H}.{I,A}

TYPE	GHITS	EXAMPLE	GLOSS
HI	1,804,407	po.lii.si	'police'
LI	1,180,225	ka.me.li	'camel'
HA	2,205,722	kor.jaa.mo	'repair shop'
LA	2,030,424	ka.me.ra	'camera'

(36) Constraint violation profiles for 3-syllable stems. Candidates that violate *UNARY, MAXφ and PARSE-STEM and have been suppressed.

		WSP/VV	WSP	FTBIN	*T	SWP	*X.H	*x/A	*x/AA	*X/I	*X/II	ALIGN-L	P-SYLL	MAX
X.H.I.X	(po.lii)(sei.ta)	1	1		1	1	2	1			1	2		
	(po.lii.sei)ta	2	2	1	1	1	1	1					1	
	(po.lii.se)ja	1	1	1		1	1	1					1	1
X.L.I.X	(ka.me)(lei.ta)				1	1		1			1	2		
	(ka.me.lei)ta	1	1	1	1	1		1					1	
	(ka.me.le)ja			1		1		1					1	1
X.H.A.X	(kor.jaa)(moi.ta)	1	1		1		2	1	1			2		
	(kor.jaa.moi)ta	2	2	1	1		1	1	2				1	
	(kor.jaa.mo)ja	1	1	1			1	2	1				1	1
X.L.A.X	(ka.me)(roi.ta)				1	1		1				2		
	(ka.me.roi)ta	1	1	1	1	1		1	1				1	
	(ka.me.ro)ja			1		1		2					1	1

(37) Two foot structures are predicted to be possible:
(a) (′x.x)(x.x) (po.lii)(sei.ta) no t-deletion
(b) (′x.x.x)x (po.lii.se)ja t-deletion

(38) Factorial typology computed by OTSoft (Hayes, Tesar and Zuraw 2003). Winners with *t*-deletion are grayed out.

Output #1	Output #2	Output #3	Output #4
(po.lii)(sei.ta)	(po.lii.se)ja	(po.lii.se)ja	(po.lii.se)ja
(ka.me)(lei.ta)	(ka.me)(lei.ta)	(ka.me)(lei.ta)	(ka.me.le)ja
(kor.jaa)(moi.ta)	(kor.jaa)(moi.ta)	(kor.jaa.mo)ja	(kor.jaa)(moi.ta)
(ka.me)(roi.ta)	(ka.me)(roi.ta)	(ka.me)(roi.ta)	(ka.me)(roi.ta)

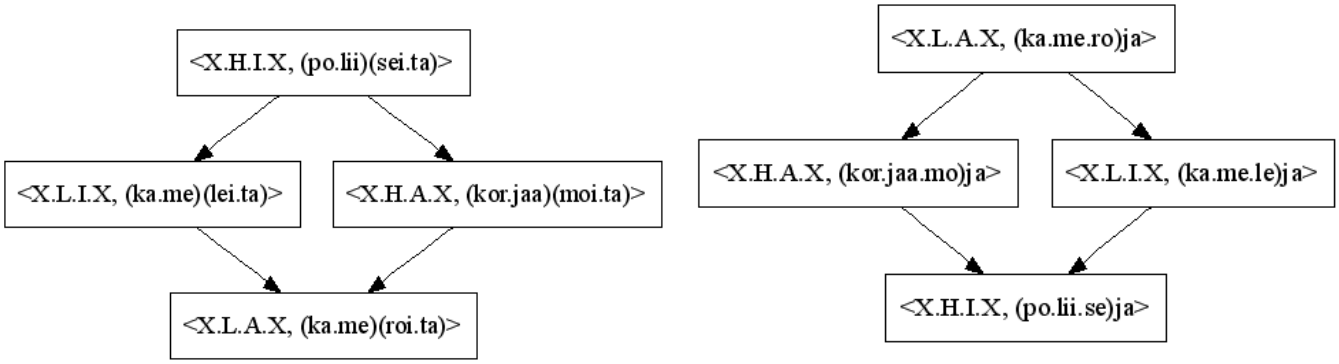
Output #5	Output #6
(po.lii.se)ja	(po.lii.se)ja
(ka.me.le)ja	(ka.me.le)ja
(kor.jaa.mo)ja	(kor.jaa.mo)ja
(ka.me)(roi.ta)	(ka.me.ro)ja

(39) Implicational universals.
- (a) *t*-deletion in /kamera/ (LA) implies deletion everywhere.
- (b) *t*-deletion in /kameli/ (LI) implies deletion in /poliisi/ (HI).
- (c) etc.

(40) T-ORDER: The set of all implicational universals in a factorial typology.

(41) **T-Order Generator (Anttila and Andrus 2006) is a Windows program that reads a factorial typology and returns the corresponding t-order as a directed graph.**

(42) T-order for trisyllabic stems

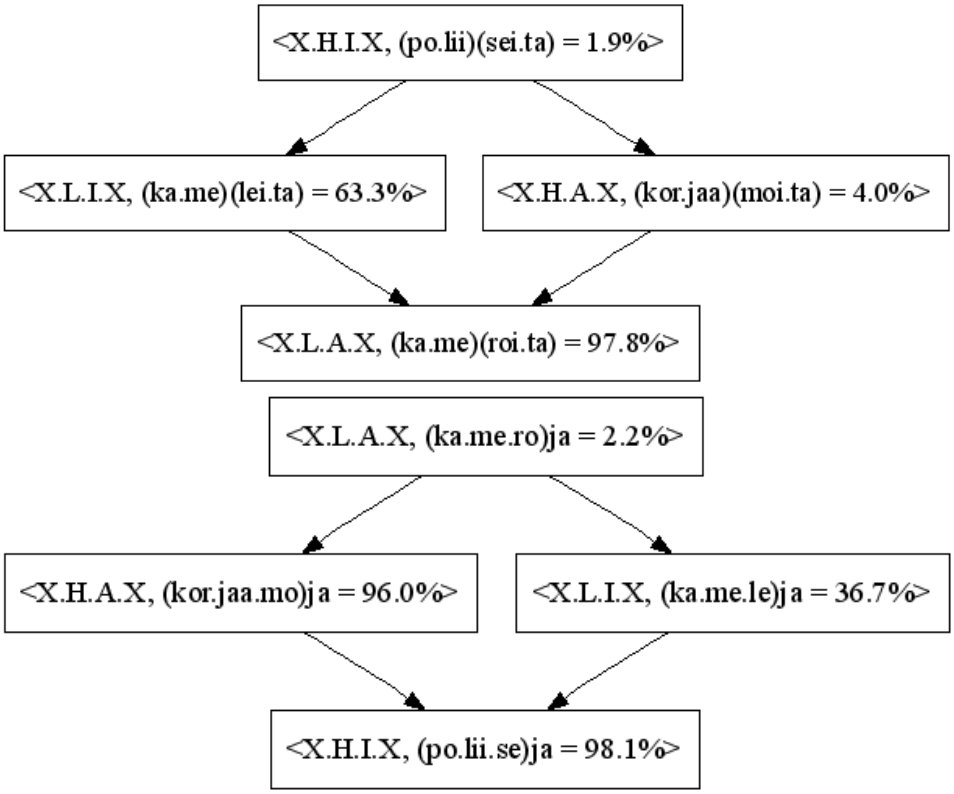


(43) Implicational universals have quantitative consequences for variation.

(44) The Multiple Grammars Theory of variation (Kiparsky 1993, Anttila 2007):
- (a) Variation arises from multiple grammars within/across individuals.
- (b) The number of grammars predicting an output is proportional to its frequency of occurrence.

(45) A quantitative prediction: The observed frequencies should grow in the direction of the arrows.

(46) The T-order annotated with observed frequencies **[SLIDE]**



(47) These predictions follow under Multiple Grammars (e.g. Kiparsky 1993), Partially Ordered Grammars (e.g. Anttila and Cho 1998) and Stochastic OT (e.g. Boersma and Hayes 2001) because the factorial typology is the same.

(48) Question: Why go through factorial typologies? Shouldn't it be possible to compute the T-order directly from constraint violations?

(49) Answer: Yes, use Elementary Ranking Conditions (ERCs, Prince 2002, 2006). Implementation in progress.

(50) Question: How well does the T-order fit the data?

(51) Answer: Check the match between actual and ideal T-orders:
(a) A = the edges predicted by the grammar.
(b) I = the edges that capture all the quantitative relationships in the data.

(52) Two evaluation metrics:
(a) Precision = $| A \cap I | / | A |$, i.e. how many of the predicted edges are correct
(b) Recall = $| A \cap I | / | I |$, i.e. how many of the correct edges are predicted

(53) In our example, precision = 1.0, recall = 0.417

4.2 Four-syllable stems

(54) Possible 4-syllable stems (12 types): X.{L,H}.{I,A,H}.{I,A}

TYPE	GHITS	EXAMPLE	GLOSS
HAI	34,612	pro.fes.so.ri	'professor'
LAI	23,595	fi.lo.so.fi	'philosopher'
HII	630,594	ar.tik.ke.li	'article'
LII	4,175	py.ra.mi.di	'pyramid'
HAA	24,479	ra.vin.to.la	'restaurant'
LAA	30	ta.pi.o.la	'Tapiola'
HIA	190,416	al.ler.gi.a	'allergy'
LIA	91,598	gal.le.ri.a	'gallery'
HHA	92,308	e.dus.tus.to	'representation'
HHI	80,063	ter.mos.taat.ti	'thermostat'
LHA	13,039	af.fri.kaat.ta	'affricate'
LHI	392,942	mar.ga.rii.ni	'margarine'

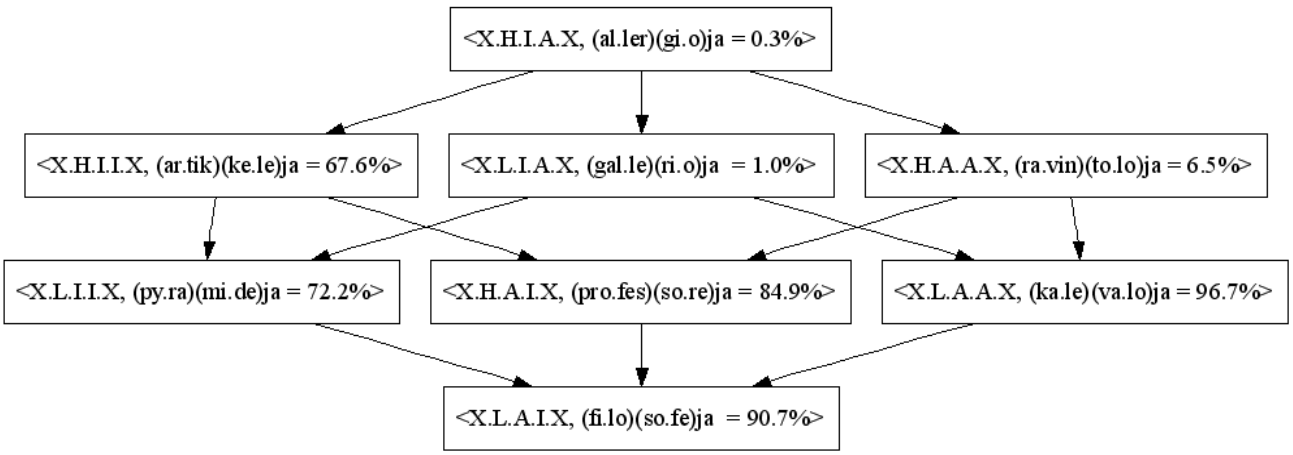
(55) Two foot structures are predicted to be possible:

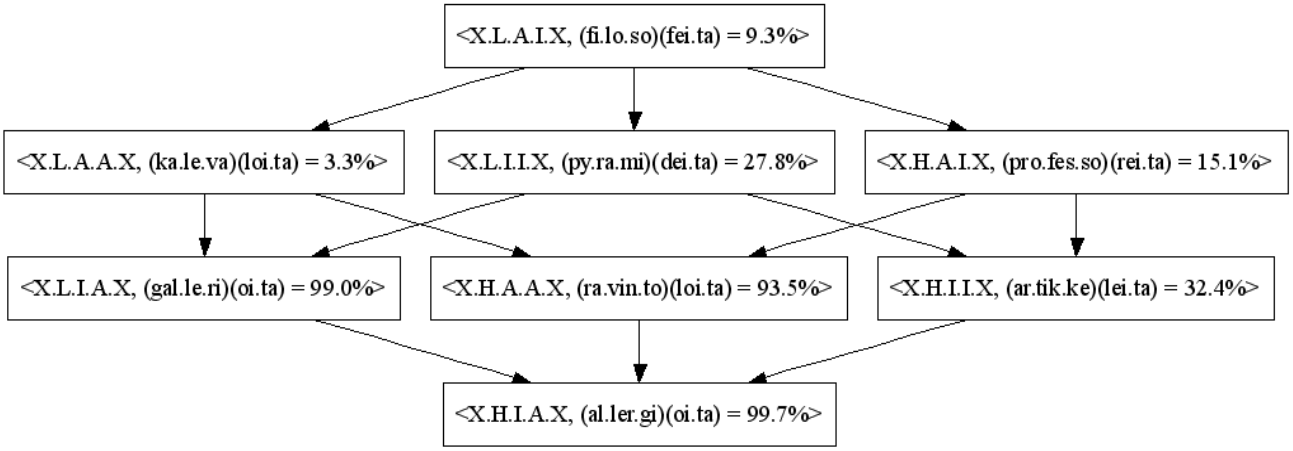
(a)	(′x.x)(x.x)x	(pro.fes)(so.re)ja	t-deletion
(b)	(′x.x.x)(x.x)	(pro.fes.so)(rei.ta)	no t-deletion

(56) *t*-deletion is predicted to be categorical for the following inputs:

TYPE		DELETION%	NON-DELETION TOKENS
HHA	(e.dus)(tus.to)ja	100.0%	22
HHI	(ter.mos)(taat.te)ja	100.0%	23
LHA	(aff.ri)(kaat.to)ja	99.7%	43
LHI	(mar.ga)(rii.ne)ja	100.0%	138

(57) T-order for the remaining stems. Precision = 0.956, recall = 0.586 **[SLIDE]**





(58) Evaluation: The binary pattern (*ka.le*)(*va.lo*)*ja* (X.L.A.A.X) occurs at a rate higher than predicted. There are only 7 such stems (30 tokens): *autostrada*, *eldorado, subimago, tapiola, telefoto, tuatara, unisono.*

(59) Diagnosis: Some of these words are compounds, e.g. *auto=strada*, *tele=foto, uni=sono*, in which case only binarity is predicted.

4.3 Five-syllable stems

(60) Possible 5-syllable stems (36 types, 28 exist): X.{L,H}.{I,A,H}.{I,A,H}.{I,A}.X.

TYPE	GHITS	EXAMPLE	GLOSS
HHIA	10,126	konsultaatio	‘consultation’
LAIA	63,717	allegoria	‘allegory’
LHIA	42,237	operaatio	‘operation’
LIIA	3,474	kommunikea	‘communiqué’
HAIA	21	responsorio	‘responsory’
HIIA	221,456	opiskelija	‘student’
LHAI	20,316	operaattori	‘operator’
LHII	2,139	inkunaabeli	‘incunable’
HHAI	1,525	kommentaattori	‘commentator’
HHII	43	liirumlaarumi	‘nonsense’
LAII	69	polyamidi	‘polyamide’
LAAI	1,990	antropologi	‘anthropologist’
LIII	296	symposiumi	‘symposium’
HIII	6	kompendiumi	‘compendium’
LIAI	66	jeremiadi	‘jeremiad’
LHHA	207	koordinaatisto	‘coordinate grid’
HAAI	23	konkvistadori	‘conquistador’
LHHI	1,128	akvarellisti	‘aquarellist’
HHHI	153	avantgardisti	‘avant-gardist’
HIAI	50	kolesteroli	‘cholesterol’
HIHA	290	evankelista	‘evangelist’
LIHI	103,312	auktoriteetti	‘authority’

HAHA	14	edustajisto	‘representation’
LAHI	9,225	adrenaliini	‘adrenalin’
LAHA	167	matematiikka	‘mathematics’
HIHI	1,884	republikaani	‘republican’
HAHI	969	konservatiivi	‘conservative’
LIHA	65	italiaano	‘Italian (person)’

(61) I have found no stems of the following 8 types in the dictionary (Tuomi 1972):

LAAA	HAAA	HAII	LIAA
HIAA	HHHA	LHAA	HHAA

(62) Three foot structures are predicted to be possible:

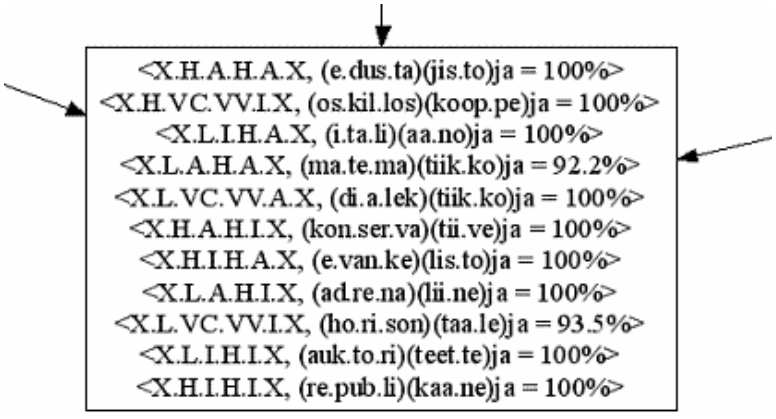
(a)	(′x.x.x)(x.x)x	(ad.re.na)(lii.ne)ja	t-deletion
(b)	(′x.x)(x.x)(x.x)	(al.le)(go.ri)(oi.ta)	no t-deletion
(c)	(′x.x)(x.x.x)x	(ak.va)(rel.lis.te)ja	t-deletion

(63) T-order: precision = 0.857, recall = 0.633 **[SLIDE]**

(64) Type 1: Initial dactyl, categorical *t*-deletion (11 types).

(ad.re.na)(lii.ne)ja	LAHI	
(ma.te.ma)(tiik.ko)ja	LAHA	
(i.ta.li)(aa.no)ja	LIHA	
(auk.to.ri)(teet.te)ja	LIHI	
(di.a.lek)(tiik.ko)ja	LHHA	(CVC.CVV)
(ho.ri.son)(taa.le)ja	LHHI	(CVC.CVV)
(e.dus.ta)(jis.to)ja	HAHA	
(kon.ser.va)(tii.ve)ja	HAHI	
(e.van.ke)(lis.to)ja	HIHA	
(re.pub.li)(kaa.ne)ja	HIHI	
(os.kil.los)(koop.pe)ja	HHHI	(CVC.CVV)

(65) Partial T-order



(66) Evaluation: In these stems, no *t*-deletion is predicted, but some is observed:

LAHA	automatiikoita (11), matematiikoita (1), pedagogiikoita (1)
LHHI	arkkitehtuureita (65), instrumentaaleita (3)
LAHI	alkoholisteita (1), automobiileita (3)
LIHI	materiaaleita (4), semifinaaleita (14), vokalisoinneita (1)

(67) In a number of cases, the predicted initial dactyl appears intuitively incorrect, e.g.

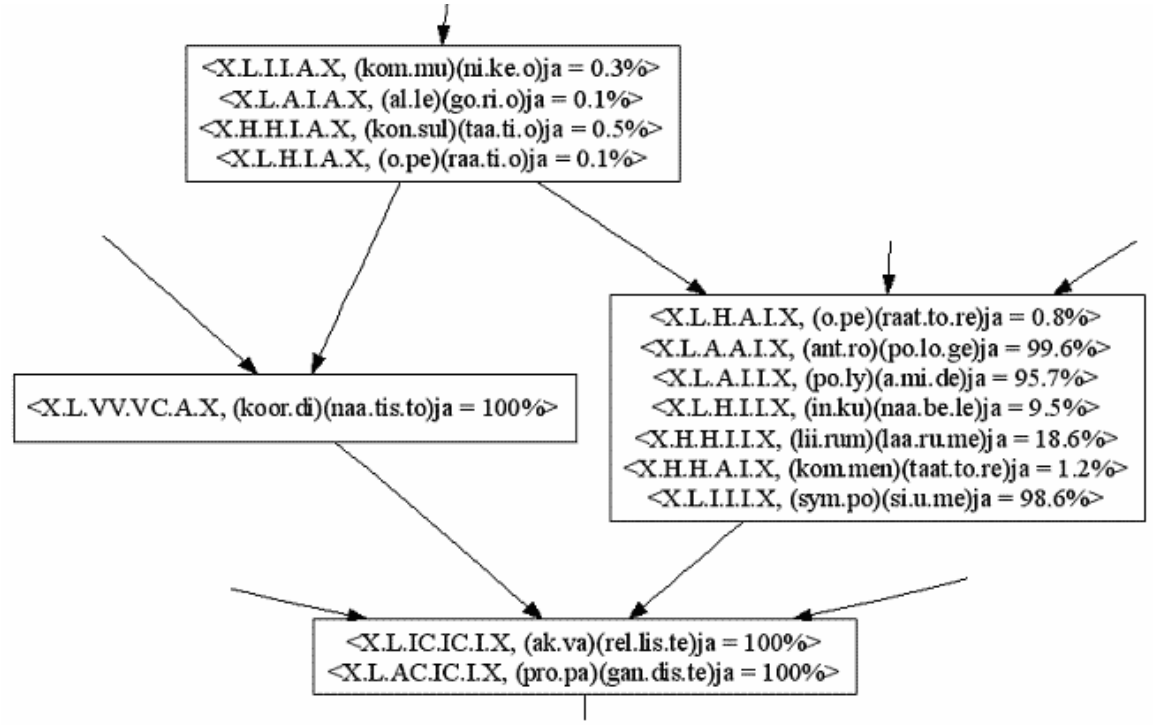
LAHI	(he.mo)(glo.bii.ne)ja	'haemoglobin-PL-PAR'	
	(her.ma)(fro.diit.te)ja	'hermaphrodite-PL-PAR'	
	(lak.to)(ba.sil.le)ja	'lactobacillus-PL-PAR'	
LIHI	(mo.no)(fy.siit.te)ja	'monophysite-PL-PAR'	(2 hits)
	cf. (mo.no.te)(is.te)ja	'monotheist-PL-PAR'	(21 hits)
	(an.ti)(se.miit.te)ja	'anti-semite-PL-PAR'	(2 hits)
	cf. (an.ti.bi)(oot.te.ja)	'antibiotic-PL-PAR'	(861 hits)

(68) Possible diagnoses:
- (a) Compounds: *árkki=tèhtuuri*, *álko=hòlisti, áuto=mòbiili*, *sémi=finaali*.
- (b) Inherently stressed suffixes: *-ìsti* in (*mo.no.te*)(*ìs.te*)*ja*
- (c) Lexical frequency: compound stress seems common in infrequent words.

(69) Type 2: Initial trochee, variable *t*-deletion (14 types).

(ant.ro)(po.lo)(gei.ta)	~	(ant.ro)(po.lo.ge)ja	LAAI	
(po.ly)(a.mi)(dei.ta)	~	(po.ly)(a.mi.de)ja	LAII	
(al.le)(go.ri)(oi.ta)	~	(al.le)(go.ri.o)ja	LAI	
(kom.mu)(ni.ke)(oi.ta)	~	(kom.mu)(ni.ke.o)ja	LIIA	
(sym.po)(si.u)(mei.ta)	~	(sym.po)(si.u.me)ja	LIII	
(o.pe)(raat.to)(rei.ta)	~	(o.pe)(raat.to.re)ja	LHAI	
(o.pe)(raa.ti)(oi.ta)	~	(o.pe)(raa.ti.o)ja	LHIA	
(in.ku)(naa.be)(lei.ta)	~	(in.ku)(naa.be.le)ja	LHII	
(koor.di)(naa.tis)(toi.ta)	~	(koor.di)(naa.tis.to)ja	LHHA	(CVV.CVC)
(pro.pa)(gan.dis)(tei.ta)	~	(pro.pa)(gan.dis.te)ja	LHHI	(CAC.CIC)
(ak.va)(rel.lis)(tei.ta)	~	(ak.va)(rel.lis.te)ja	LHHI	(CIC.CIC)
(kom.men)(taat.to)(rei.ta)	~	(kom.men)(taat.to.re)ja	HHAI	
(lii.rum)(laa.ru)(mei.ta)	~	(lii.rum)(laa.ru.me)ja	HHII	
(kon.sul)(taa.ti)(oi.ta)	~	(kon.sul)(taa.ti.o)ja	HHIA	

(70) Partial T-order



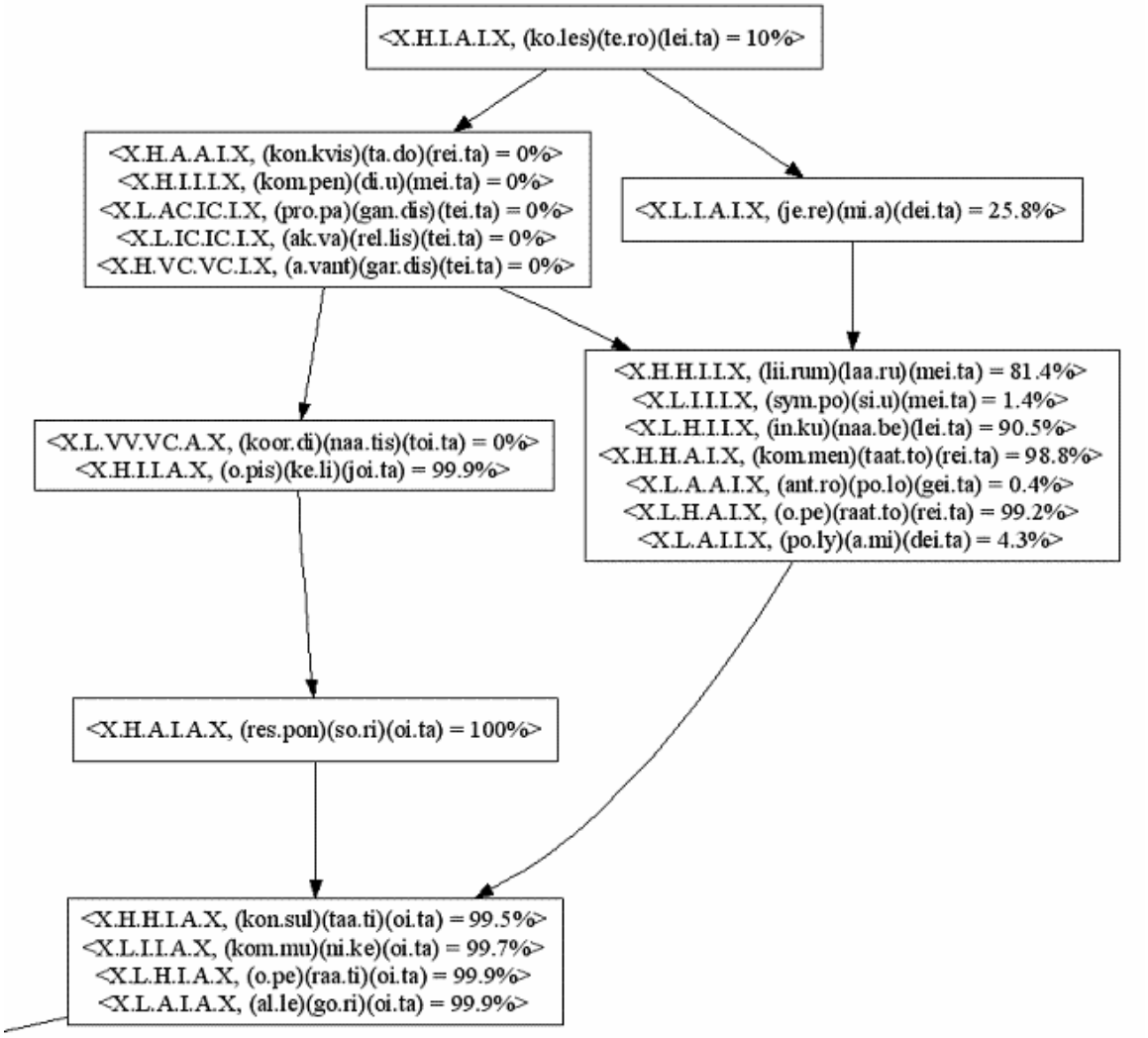
(71) Evaluation: The box on the right has both very high and very low values. Some intuitively incorrect stress patterns are predicted as well, e.g. *(*ant.ro*)(*po.lo.ge*)*ja* instead of (*ant.ro.po*)(*lo.ge*)*ja*

(72) Diagnosis: The stems with high deletion values typically have learned prefixes and suffixes, e.g. *poly-*, *-logi* '-logist', *-grafi* '-grapher', which appear to constitute prosodic words on their own, i.e. again we have compounds.

(73) Type 3: Initial trochee or dactyl, variable *t*-deletion (7 types)

(je.re)(mi.a)(dei.ta)	~ (je.re.mi)(a.de)ja	~ (je.re)(mi.a.de)ja	LIAI
(res.pon)(so.ri)(oi.ta)	~ (res.pon.so)(ri.o)ja	~ (res.pon)(so.ri.o)ja	HAIA
(kon.kvis)(ta.do)(rei.ta)	~ (kon.kvis.ta)(do.re)ja	~ (kon.kvis)(ta.do.re)ja	HAAI
(ko.les)(te.ro)(lei.ta)	~ (ko.les.te)(ro.le)ja	~ (ko.les)(te.ro.le)ja	HIAI
(o.pis)(ke.li)(joi.ta)	~ (o.pis.ke)(li.jo)ja	~ (o.pis)(ke.li.jo)ja	HIIA
(kom.pen)(di.u)(mei.ta)	~ (kom.pen.di)(u.me)ja	~ (kom.pen)(di.u.me)ja	HIII
(a.vant)(gar.dis)(tei.ta)	~ (a.vant.gar)(dis.te)ja	~ (a.vant)(gar.dis.te)ja	HHHI

(74) Partial T-order



(75) Evaluation: Similar remarks apply.

9. Conclusions

(76) Optimality Theory predicts typological generalizations (T-ORDERS)

(77) These generalizations are reflected quantitatively in language variation

(78) Evidence: Variable word stress in Finnish. The relevant factors include syllable weight (CVV/CVC vs. CV), syllable closure (CVV vs. CVC), vowel sonority, prominence clash, morphology, and perhaps even lexical frequency.

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