Variation in Optimality Theory, IU Phonology Fest, 19-22 June, 2006 *Handout #1*
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VARIATION AND GRADIENCE IN OPTIMALITY THEORY

1. Phenomena

(1) Variation in form (= variation), variation in meaning (= ambiguity)

(2) Far from being a marginal "performance" phenomenon, variation is central to human language and an exciting source of evidence about its structure.

(3) Examples of variation in phonology, morphology, and syntax:
- (a) English: *west bank ~ wes' bank*
- (b) Finnish: *má.ke.a ~ má.kee* ' sweet', *lá.si.-a ~ lá.si-i* 'glass-PAR'
- (c) Finnish: *omeno-iden ~ omen-ien ~ omeno-itten ~ omena-in* 'apple-PL.GEN'
- (d) English: *Transactions of the Philological Society ~ Philological Society's Transactions* (Jespersen 1949:314)

(4) Variation may have sociolinguistic and stylistic conditions (external factors):
- (a) English *t,d*-deletion [see references in Labov 1997]
- (b) Vowel Coalescence in Colloquial Helsinki Finnish (Paunonen 1995:112, Anttila in press): favored by young working class speakers; disfavored by old upper class speakers, especially females.
- (c) Finnish Genitive Plural: no evidence for sociolinguistic or stylistic conditioning in *omeno-iden ~ omen-ien ~ omeno-itten*, whereas *omena-in* sounds old-fashioned, e.g. in Mika Waltari's (1908-1979) early novels.
- (d) English possessives: ?

(5) Variation may have grammatical conditions (internal factors, this course):
- (a) English *t,d*-deletion depends on onset structure, neighboring segments (OCP), morphology, and lexical frequency (Bybee 2002, Coetzee 2004, Côté 2000, Guy 1980, 1991ab, 1994, 1997ab, Guy and Boberg 1997, Guy and Boyd 1990, Guy and Myers 1997, Kiparsky 1993, Labov 1997):

MORE DELETION	LESS DELETION	CONDITION
west bank, lost Lenny	*west end, lost Renny*	syllable structure
list (cf. *act*[ə]*d*, Nycz 2005)	*lift*	segmental OCP
los+t	*toss#ed*	level 1 vs. level 2
pass#ed	*kiss#ed*	lexical frequency

(b) Finnish Vowel Coalescence depends on vowel height, morpheme boundary, and lexical category (Anttila in press):

MORE COALESCENCE	LESS (OR NO) COALESCENCE	CONDITION
súo.me-a 'Finnish-PAR'	*rúot.si-a* 'Swedish-PAR'	vowel height
lá.si-a 'glass-PAR'	*rá.si.a* 'box-PAR' (**rá.sii*)	morph. bound.
má.ke.a 'sweet, a.'	*í.de.a* 'idea, n.' (**í.dee*)	lex. category

(c) Finnish morphology is sensitive to optional secondary stress which is itself sensitive to syllable weight and vowel height [more later].

(d) English possessives (e.g. Anttila and Fong 2004, Rosenbach 2005):

MORE S-GENITIVE	MORE OF-GENITIVE
animate NP, *Kim*	inanimate NP, *the book*
high theta role, e.g. agent	low theta role, e.g. theme
discourse-old NP	discourse-new NP
non-relational head, e,g, *cat*	relational head, e.g. *picture, performance*
short NP	long NP (Is this phonology?)

Both variation in form and variation in meaning:
their performance vs. *the performance of them*

(6) Research questions:
- (a) The locus of variation: Why does variation occur in certain environments, but is blocked in others?
- (b) The degrees of variation: What determines the quantitative preferences among the variants?
- (c) Grammar and context: How are internal and external factors related?

(7) Variation cannot be reduced to phonetics, sociolinguistics, etc. It is deeply embedded in grammar and refers to grammatical variables:
- onset structure, segmental OCP, stress, syllable weight, vowel height
- level ordering, morpheme boundaries, lexical categories
- animacy, thematic roles, discourse novelty, lexical semantics

2. Modeling variation in OT

(8) *t,d*-deletion in American English:
- (a) It cost ~ cos five dollars. (*t* before a consonant)
- (b) It cost ~ cos us five dollars. (*t* before a vowel)
- (c) That's how much it cost ~ cos. (*t* before a pause)

(9) Data from five dialects (Coetzee 2004: 218):

		_C	_V	_##
Chicano English (Los Angeles)	*n*	3,693	1,574	1,024
(Santa Ana 1991:76, 1996:66)	% deleted	62	45	37
Tejano English (San Antonio)	*n*	1,738	974	564
(Bayley 1995:310)	% deleted	62	25	46
AAE (Washington, DC)	*n*	143	202	37
(Fasold 1972:76)	% deleted	76	29	73
Jamaican mesolect (Kingston)	*n*	1,252	793	252
(Patrick 1991:181)	% deleted	85	63	71
Trinidadian acrolect	*n*	22	43	16
(Kang 1994:157)	% deleted	81	21	31
Neu data	*n*	814	495	--
(Neu 1980:45)	% deleted	36	16	--

(10) (a) In all dialects, deletion rate is highest in _C.
(b) Deletion rates in _V and _## may occur in either order.

(11) Optimality Theory (Prince and Smolensky 1993/2004):
(a) Grammatical constraints make potentially conflicting structural demands.
(b) Conflicts among constraints are resolved by strict ranking.
(c) Constraints are universal, rankings are language-specific.

(12) Constraints (Kiparsky 1993):

*COMPLEX	Avoid consonant clusters within a syllable.
ONSET	Syllables have onsets.
PARSE	Segments belong to syllables.
ALIGN-LEFT-WORD	Syllables cannot straddle word boundaries.
ALIGN-RIGHT-PHRASE	Phrase-final consonants are also syllable-final.

(13) Sample ranking. Winners: *cost us* (no deletion), *cos me* (deletion), *cos* (deletion)

INPUTS	OUTPUTS	*COMPLEX	ONSET	ALIGN-L-W	ALIGN-R-P	PARSE
cost us	(a) [cost][us]	*!	*			
	(b) [cos]t[us]		*!			*
	(c) → [cos][tus]			*		
cost me	(a) [cost][me]	*!				
	(b) → [cos]t[me]					*
	(c) [cos][tme]	*!		*		
cost	(a) [cost]	*!				
	(b) → [cos]t				*	*

(14) What kinds of languages are predicted? Use OTSOFT (Hayes, Tesar, and Zuraw 2003) to compute the <u>factorial typology.</u> *t,d*-deletion is highlighted.

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With 5 constraints, the number of logically possible grammars is 120.
There were 6 different output patterns.

             Output #1    Output #2    Output #3    Output #4
/cost us/:   [cost][us]   [cos]t[us]   [cos]t[us]   [cos][tus]
/cost me/:   [cost][me]   [cos]t[me]   [cos]t[me]   [cost][me]
/cost/:      [cost]       [cost]       [cos]t       [cost]

             Output #5    Output #6
/cost us/:   [cos][tus]   [cos][tus]
/cost me/:   [cos]t[me]   [cos]t[me]
/cost/:      [cost]       [cos]t
```

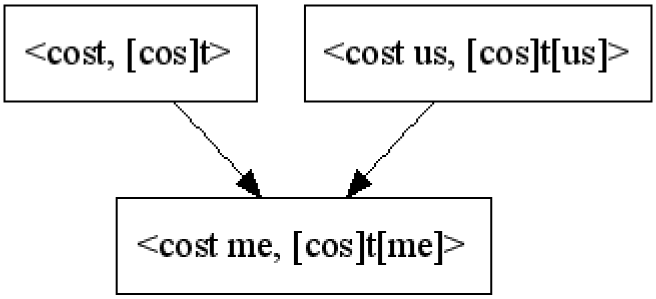
(15) Only four types of deletion systems are predicted (Kiparsky 1993:4):
- (a) Deletion before C
- (b) Deletion before {C, V}
- (c) Deletion before {C, pause}
- (d) Deletion before {C, V, pause}, i.e. everywhere.

(16) <u>Implicational universal</u>: If *t,d*-deletion occurs before a vowel or a pause, it also occurs before a consonant.

(17) This implicational universal follows from the constraints in (12), but it was not obvious from either the tableau or the factorial typology. Maybe there are more?

(18) Factorial typology: 2 × 2 table with an <input, output> pair in each cell:
- (a) If <*cost*, [*cos*]*t*> is in a dialect, so is <*cost me*, [*cos*]*t*[*me*]>.
- (b) If <*cost us*, [*cos*]*t*[*us*]> is in a dialect, so is <*cost me*, [*cos*]*t*[*me*]>.

(19) The implicational universal in (16) stated graphically



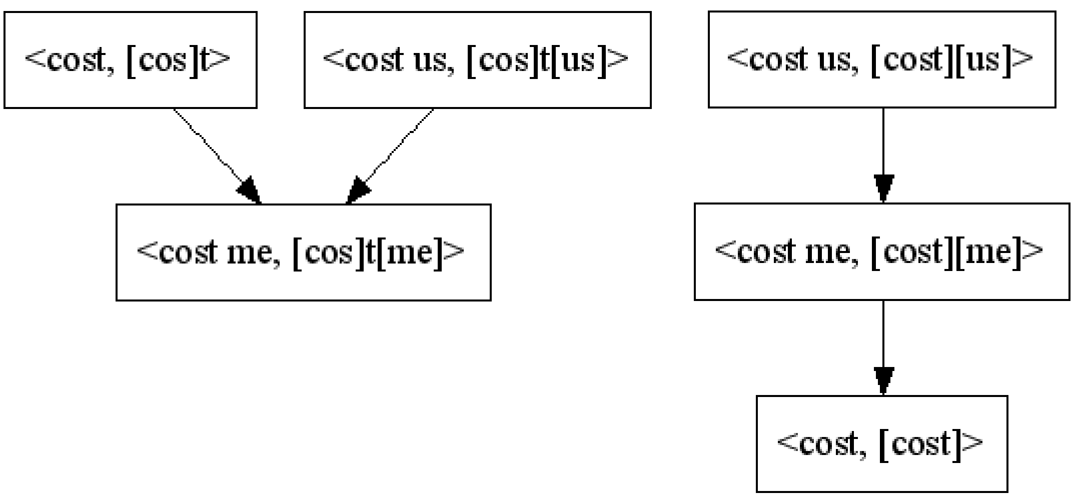
(20) t-order: The set of all implicational universals in a factorial typology

(21) Problem: Factorial typologies are hard for humans to understand. Working out the t-order with paper and pencil is tedious.

(22) Solution: T-Order Constructor (Anttila and Andrus 2006), see Appendix.

T-Order-Constructor is a Windows program that takes a factorial typology as input and returns the corresponding t-order as a directed graph.

(23) The t-order for the constraint set in (12)



(24) But how about variation and quantitative patterns?

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

(26) Example: Assume an individual with three total rankings of types {#1, #5, #6}. In the long run, this individual's *t,d*-deletion rates will approximate 0, 2/3, and 1/3.

	Output #1	Output #5	Output #6	Del. rate
/cost us/:	[cost][us]	[cos][tus]	[cos][tus]	0/3
/cost me/:	[cost][me]	[cos]t[me]	[cos]t[me]	2/3
/cost/:	[cost]	[cost]	[cos]t	1/3

(27) Consequence: There is no combination of grammars with more *t,d*-deletion before vowels or pauses than before consonants.

(28) In other words, the numbers can only grow in the direction of the arrows.

(29) Quantitative predictions = the empirical generalizations in (10):
- (a) Deletion rate before {V, pause} can never exceed deletion rate before C.
- (b) Nothing is predicted about the ordering of V and pause.

(30) Two types of quantitative patterns:
- (a) Quantitative universals are ranking-independent and follow directly from the constraints (= t-order).
- (b) Quantitative particulars are ranking-dependent and hence subject to cross-linguistic variation.

(31) Why are t-orders interesting?
- (a) t-orders are a consequence of OT, not a new theoretical device.
- (b) t-orders are universal and do not have to be learned.
- (c) t-orders are general: they hold true under several theories of variation, e.g. Multiple Grammars (Kiparsky 1993), Partially Ordered Grammars (Anttila and Cho 1998), and Stochastic OT (Boersma and Hayes 2001). This is because in all these theories the factorial typology is the same [more later].
- (d) t-orders diagnose the adequacy of constraints. If the t-order conflicts with the empirical typology, you will need different constraints.
- (e) t-orders express relative well-formedness across inputs [more later].

(32) Question: Why must we go through the factorial typology? Shouldn't it be possible to compute the t-order directly from the constraint violation tableau?
Answer: Yes, it should be possible. Any ideas?

(33) A first stab: Let A, B be two <input, output> pairs. If A incurs a superset of B's violations, then A precedes B in the t-order. Example: <*cost us*, [*cos*]*t us*> violates both ONSET and PARSE, <*cost me*, [*cos*]*t me*> only violates PARSE; and the former precedes the latter in the t-order.

(34) Problem: Consider the exhaustively syllabified pairs: <*cost me*, [*cost*] [*me*]> precedes <*cost*, [*cost*]> in the t-order, yet both only violate *COMPLEX. The asymmetry must arise from their respective competitor sets, but exactly how?

3. Modeling gradient phonotactics in OT

(35) Gradient phonotactic generalizations are a challenge for OT (and for any theory of phonology). See e.g. Berkley 2000, Coleman and Pierrehumbert 1997, Frisch et al. 2004, Hay et al. 2003, McCarthy 1988, 1994, Pater 2004, Pater and Coetzee 2005, Pierrehumbert 1993 [Additions to this list would be welcome.]

(36) Pater and Coetzee 2005 (henceforth P&C) propose an OT solution. The following discussion follows up on their insights.

(37) In Arabic, there is a restriction against homorganic consonants in adjacent positions within the verbal root (Greenberg 1950; McCarthy 1988, 1994; Pierrehumbert 1993, Frisch et al. 2004, Pater and Coetzee 2005).

(38) Observed/Expected ratios for adjacent consonants in Arabic verbal roots (Frisch et al. 2004, 186). Following P&C, I have omitted (i) dorsals and gutturals and (ii) non-adjacent consonants.

	labial	dorsal	coronal sonorant	coronal fricative	coronal plosive
labial	0.00				
dorsal	1.15	0.02			
coronal sonorant	1.18	1.48	0.06		
coronal fricative	1.31	1.16	1.21	0.04	
coronal plosive	1.37	0.80	1.23	0.52	0.14

labial: b,f,m
dorsal: k, g, q
coronal sonorant: l, r, n
coronal fricative: θ, ð, s, z, sˤ, zˤ, ʃ
coronal plosive: t, d, tˤ, dˤ

(39) O/E values for pairs of homorganic consonants are near zero, but within coronals there is gradience. The segment combinations can be divided in three groups:
A: If the coronals are both sonorants, fricatives, or plosives, O/E is low.
B: If the coronals are fricative + plosive, the O/E ratio is higher.
C: If the coronals are sonorant + fricative or plosive, O/E is high.

(40) P&C posit the following constraints:

OCP-COR	No adjacent coronals
OCP-COR[+SON]	No adjacent coronal sonorants.
OCP-COR[−SON]	No adjacent coronal obstruents.
OCP-COR[−SON][αCONT]	No adjacent coronal obstruents agreeing in [±cont].
FAITH	The input and the output are identical.

(41) P&C propose the following ranking for Arabic:

OCP-LAB >>	{ OCP-COR[−SON][αCONT] OCP-COR[+SON] }	>> OCP-COR[−SON]	>> OCP-COR
violations lead to total ill-formedness	violated by A, low O/E	violated by B, intermediate O/E	violated by C, high O/E

(42) But how about gradience? [t-s] is of intermediate well-formedness, so where should FAITH be ranked?

(a) By this ranking, [t-s] is perfectly well-formed.

		OCP-lab	OCP-cor [−son, αcont]	OCP-cor [+son]	FAITH	OCP-cor [−son]	OCP-cor
t-s	→ t-s					*	*
	OTHER				*!		

(b) By this ranking, [t-s] is perfectly ill-formed.

		OCP-LAB	OCP-cor [−son, αcont]	OCP-cor [+son]	OCP-cor [−son]	FAITH	OCP-cor
t-s	t-s				*!		*
	→ OTHER					*	

(43) P&C: "If the ranking between these constraints is allowed to vary each time the grammar is employed, as in models like those of Anttila (1997) and Boersma (1998), then a word with stop-fricative pair will vary between a faithful output, and one that is altered (for example by deleting, or changing the place, of one of the segments). But lexical items in Arabic that have stop-fricative pairs are not reported to show variation."

(44) Frisch et al. (2004, 191): "Under versions of OT that permit stochastic constraint ranking, such as Boersma and Hayes (2001), probabilistic variation in the outcomes would result in probabilistic variation for all words, not in diffierential probabilities in the lexicon. In addition, the cumulative interaction of similarity in all dimensions is problematic to formalize in OT."

(45) P&C's solution: Lexically indexed faithfulness constraints

		OCP-lab	**FAITH-L2**	OCP-cor [−son, αcont]	OCP-cor [+son]	**FAITH-L1**	OCP-cor [−son]	**FAITH**	OCP-cor
p-m	p-m	*!							
	→OTHER		(*)			(*)		(*)	
t-d	t-d			*			*		*
	OTHER		(*)			(*)		(*)	
t-s	t-s						*		*
	OTHER		(*)			(*)		(*)	
t-n	t-n								*
	OTHER		(*)			(*)		(*)	

(46) P&C's assumption: Each word is submitted to the grammar with each lexical indexation. The more often it surfaces faithfully, the more acceptable it is.

(47) Example: By indexing /t-d/ to FAITH-L2, FAITH-L1 and FAITH, [t-d] wins in 1/3 of the indexations, i.e. /t-d/ → [t-d] is 33% well-formed

		OCP-lab	**FAITH-L2**	OCP-cor [−son, αcont]	OCP-cor [+son]	**FAITH-L1**	OCP-cor [−son]	**FAITH**	OCP-cor
t-d	→t-d			*			*		*
	OTHER		*!			(*)		(*)	
t-d	t-d			*!			*		*
	→OTHER		*			*		(*)	
t-d	t-d			*!			*		*
	→OTHER		*			*		*	

(48) The predicted ordering:

(a)	/p-m/ → [p-m]	0/3	/t-s/ → [t-s]	2/3
(b)	/t-d/ → [t-d]	1/3	/t-n/ → [t-n]	3/3

(49) <u>Intuition</u>: Quantitative phonotactic generalizations reflect typological well-formedness relations among input-output mappings. For example, if /t-d/ → [t-d] under a given ranking, then /t-s/ → [t-s] under the same ranking.

(50) This is exactly what t-orders express.

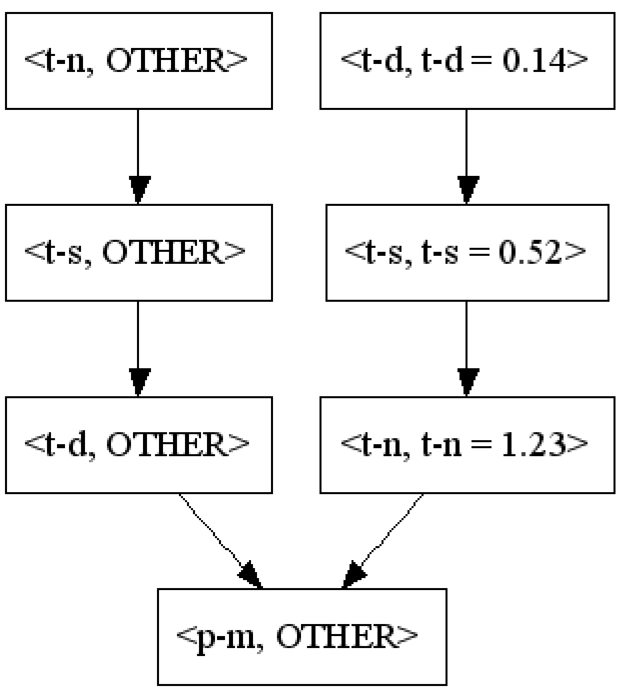
(51) Assume that there is only one freely ranked FAITH constraint:

		FAITH	OCP-lab	OCP-cor [−son, αcont]	OCP-cor [+son]	OCP-cor [−son]	OCP-cor
p-m	p-m		*!				
	OTHER	*					
t-d	t-d			*		*	*
	OTHER	*					
t-s	t-s					*	*
	OTHER	*					
t-n	t-n						*
	OTHER	*					

(52) Given P&C's ranking, we derive the following factorial typology. (In fact, the rankings among OCP-COR constraints turn out unnecessary.)

```
         Output #1   Output #2   Output #3   Output #4
/p-m/:   >OTHER      >OTHER      >OTHER      >OTHER
/t-d/:   >OTHER      >OTHER      >OTHER       t-d
/t-s/:   >OTHER      >OTHER       t-s         t-s
/t-n/:   >OTHER       t-n         t-n         t-n
```

(53) t-order

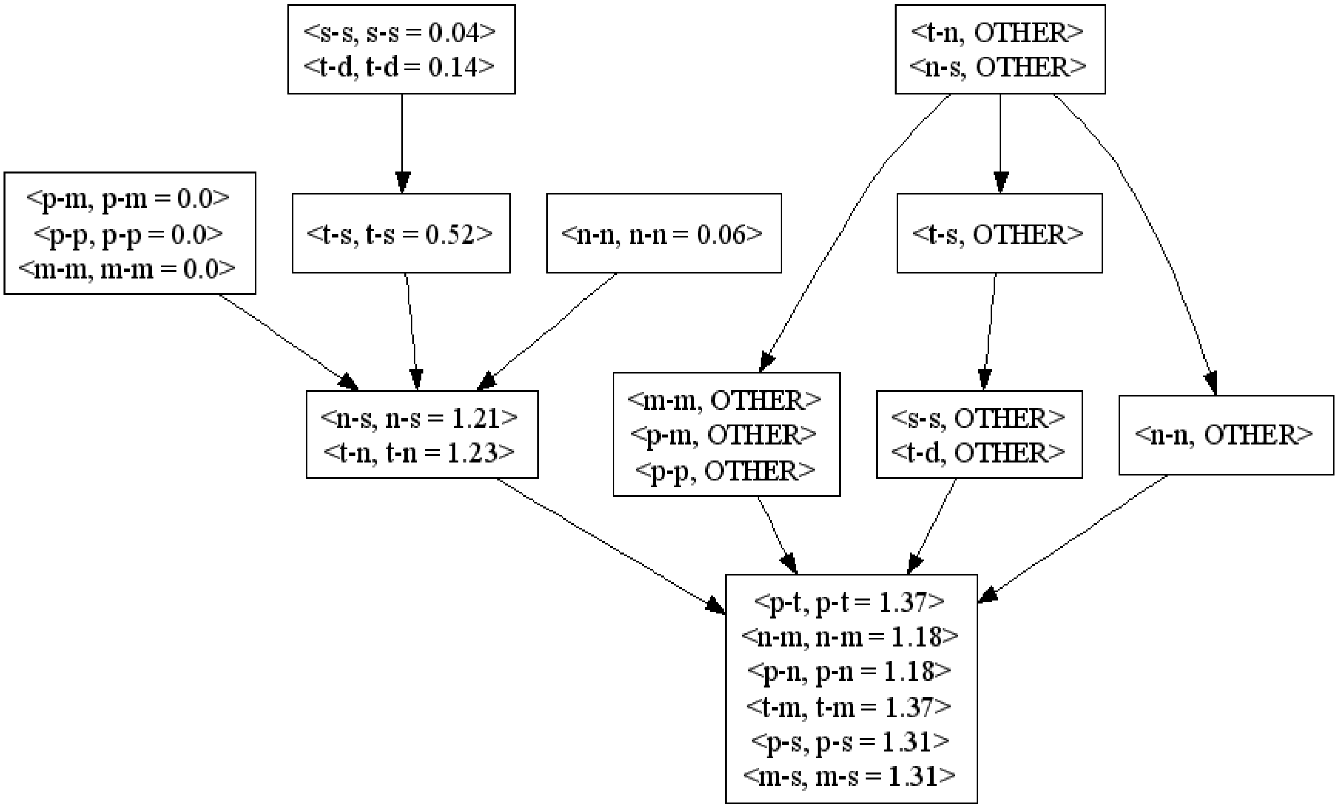


(54) <u>Conclusion</u>: Gradient phonotactic generalizations are another reflex of t-orders.

(55) Let us generalize P&C's proposal further by (i) adding more inputs and (ii) leaving out all rankings. In addition, we replace OCP-COR by OCP-LAB/COR (Kiparsky 1994, De Lacy 2002). [This gets us another correct prediction.]

		FAITH	OCP-lab	OCP-lab/cor	OCP-cor[+son]	OCP-cor[−son]	OCP-cor[−son, αcont]
p-s	p-s						
	OTHER	*					
p-m	p-m		*	*			
	OTHER	*					
p-n	p-n						
	OTHER	*					
p-t	p-t						
	OTHER	*					
t-s	t-s			*		*	
	OTHER	*					
t-m	t-m						
	OTHER	*					
t-n	t-n			*			
	OTHER	*					
n-s	n-s			*			
	OTHER	*					
n-m	n-s						
	OTHER	*					
m-s	m-s						
	OTHER	*					
p-p	p-p		*	*			
	OTHER	*					
t-d	t-d			*		*	*
	OTHER	*					
n-n	n-n			*	*		
	OTHER	*					
m-m	m-m		*	*			
	OTHER	*					
s-s	s-s			*		*	*
	OTHER	*					

(56) t-order



(57) The ordering [t-d] < [t-s] < [t-n] still holds. One prediction is gained, one lost:

- The bottom node (different places of articulation) is correctly ordered, except for the 1.18 values, which point at a slight problem in P&C's constraints.
- [p-m] is no longer typologically worse than [t-d] and [t-s] because OCP-LAB >> the rest no longer holds, so we should put it back.

(58) <u>Question</u>: What is the relationship between the grammar and the lexicon?

(59) <u>Answer, Part 1</u>: The phonology of a language is a PARTIAL ORDER (Anttila 2002) that defines a space of typological options. For example, in Arabic we have

OCP-LAB >> {
OCP-COR[−SON][αCONT]
OCP-COR[+SON]
OCP-COR[−SON]
OCP-LAB/COR
}

	Output #1	Output #2	Output #3	Output #4
/p-m/:	>OTHER	>OTHER	>OTHER	>OTHER
/t-d/:	>OTHER	>OTHER	>OTHER	t-d
/t-s/:	>OTHER	>OTHER	t-s	t-s
/t-n/:	>OTHER	t-n	t-n	t-n

Answer, Part 2: Lexical items are associated with different parts of this grammatical space, i.e. there are lexical rankings (Anttila 2002). The existence of quantitative phonotactic generalizations shows that the lexicon is a random sampling of the available phonological space.

4. Summary

(60) An OT grammar defines a set of implicational universals that hold among <input, output> pairs. We call this structure a T-ORDER.

(61) T-orders constrain at least three types of <input, output> mappings:
- (a) Within alternation: the same alternation in different environments, e.g. English prevocalic and prepausal deletion: <*cost us*, [*cos*]*t* [*us*]> → <*cost me*, [*cos*]*t* [*me*]>
- (b) Across alternations: different alternations in different environments, e.g. Singapore English prevocalic *p*-copy and prepausal *sp*-metathesis (Anttila, Fong, Benus, and Nycz 2004): <lisp-ing, [lipsping]> → <lisp, [lips]>
- (c) Gradient phonotactics: faithful mappings across different environments, e.g. OCP effects in Arabic: <t-d, [t-d]> → </t-s/, [t-s]>

(62) T-orders are reflected both categorically and quantitatively.

5. Alternatives to multiple grammars

(63) The Multiple Grammars Theory is the generic theory of variation.

5.1. Partially Ordered Grammars

(64) Finnish Vowel Coalescence: *má.ke.a~má.kee* 'sweet', *lá.si.-a~lá.si-i* 'glass-PAR'.

(65)
*EA	Avoid /ea, oa, öä/ hiatus.
*IA	Avoid /ia, ua, yä/ hiatus.
FAITH	No coalescence.

(66) Coalescence is more common in mid vowels (*ea*) than high vowels (*ia*) (Paunonen 1995:106-114). Solution: Fixed ranking *EA >> *IA

(67) The constraint violation pattern

/suome-a/ 'Finnish-PAR'	FAITH	*EA	*IA
(a) suomea		*	
(b) suomee	*		
/ruotsi-a/ 'Swedish-PAR'	FAITH	*EA	*IA
(c) ruotsia			*
(d) ruotsii	*		

(68) Assuming the fixed ranking *EA >> *IA, we get the following factorial typology:

		suome-a	*ruotsi-a*
(a)	FAITH >> *EA >> *IA	*suome-a*	*ruotsi-a*
(b)	*EA >> FAITH >> *IA	***suome-e***	*ruotsi-a*
(c)	*EA >> *IA >> FAITH	***suome-e***	***ruotsi-i***

(69) A Partially Ordered Grammar (Anttila 1997, Anttila and Cho 1998, Auger 2001, Ringen and Heinämäki 1999, Zamma 2005; most analyses in Reynolds 1994) is a binary relation (= set of ordered pairs) which is irreflexive, asymmetric, and transitive. Any partial order can be translated into a set of total orders, but not vice versa.

(70) Within the factorial typology in (68) there are 6 partial orders:

(a,b,c)
Colloquial Helsinki Finnish
*EA >> *IA
ea~ee, ia~ii

(a,b)
Old Töölö
*EA >> *IA
FAITH >> *IA
ea~ee, ia

(b,c)
Western Uusimaa
*EA >> *IA
*EA >> FAITH
ee, ia~ii

(a)
Literary Finnish
*EA >> *IA
FAITH >> *EA
FAITH >> *IA
ea, ia

(b)
General Häme
*EA >> *IA
*EA >> FAITH
FAITH >> *IA
ee, ia

(c)
(unattested)
*EA >> *IA
*EA >> FAITH
*IA >> FAITH
ee, ii

(71) The typology of invariant dialects:

(a)	*suome-a*	*ruotsi-a*	No coalescence anywhere.
(b)	***suome-e***	*ruotsi-a*	More coalescence in *ea* than *ia*.
(c)	***suome-e***	***ruotsi-i***	Coalescence everywhere.

(72) The typology of variable dialects:

(a,b)
suome-a *ruotsi-a*
suome-e *ruotsi-a*
More coalescence in *ea* than *ia*.

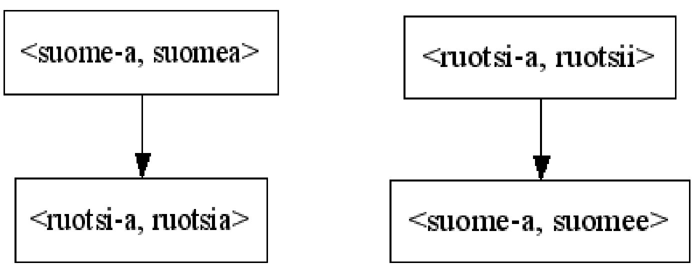
(b,c)
suome-e *ruotsi-a*
suome-e ***ruotsi-i***
More coalescence in *ea* than *ia*.

(a,b,c)
suome-a *ruotsi-a*
suome-e *ruotsi-a*
suome-e ***ruotsi-i***
More coalescence in *ea* than *ia*.

(73) The generic Multiple Grammars Theory allows an additional variable grammar where *ea* and *ia* coalesce at an equal rate:

(a,c) *suome-a* *ruotsi-a* No coalescence anywhere.
suome-e ***ruotsi-i*** Coalescence everywhere.

(74) Partially Ordered languages are a subset of Multiple Grammars languages, but the t-order remains the same.



5.2 Stochastic Optimality Theory

(75) In StOT (Boersma 1998, Boersma and Hayes 2001, Hayes to appear, Zuraw 2000, among others) each constraint is associated with a real-number ranking value.

(76) Stochastic candidate evaluation: A random positive or negative value ("noise") is temporarily added to the ranking value of each constraint at evaluation time. The resulting selection points are normally distributed around the ranking value.

(77) Gradual Learning Algorithm (GLA, Boersma and Hayes 2001) for StOT:
(a) Input: a set of arbitrarily ranked constraints, </input/, [output]> pairs
(b) If the current ranking generates the current learning datum, do nothing.
If the current ranking does not generate the current learning datum, then
- For every constraint violated by the learning datum (= desired winner), decrease its ranking value by a small step.
- For every constraint violated by the current winner (= wrong winner), increase its ranking value by a small step.

(78) GLA can cope with variation because the adjustments are very small.

(79) Finnish Vowel Coalescence (regular nouns only):

		FREQ	*EA	*IA	FAITH$_{Rt}$	FAITH
(a) /suome-a/	suomea	421	*			
‘Finnish-PAR’	suomee	293				*
(b) /idea/	idea	12	*			
‘idea’	idee	0			*	*
(c) /ruotsi-a/	ruotsia	4045		*		
‘Swedish-PAR’	ruotsii	1014				*
(d) /lattia/	lattia	847		*		
‘floor’	lattii	0			*	*

(80) The result of a representative test run (50,000 learning trials, 2,000 test cycles): FAITH$_{root}$ = 106.240, FAITH = 101.306, *EA = 100.568, *IA = 98.126. Average error 2.414 % per candidate

F$_{root}$ F *EA *IA

107 106 105 104 103 102 101 100 99 98

(81) Observations and predictions:

	OBS%	PRED%	EXAMPLE	GLOSS	n
/e-a/, NOUN	0.410	0.420	/suome-a/	‘Finnish-PAR’	714
/ea/, NOUN (recent)	0.000	0.016	/idea/	‘idea’	12
/i-a/, NOUN	0.200	0.130	/ruotsi-a/	‘Swedish-PAR’	5,059
/ia/, NOUN	0.000	0.001	/lattia/	‘floor’	847

(82) Predicts **idee, *lattii* marginally. Increasing the number of exposures will eliminate these forms: with 100,000,000 learning trials and 50,000 test cycles, FAITH$_{root}$ reached the ranking value 114.000, a virtually categorical pattern.

(83) The same factorial typology, hence the same t-order.

(84) If all constraints have the same standard deviation, then stable grammars like {C >> A >> B}, {A >> C >> B}, {A >> B >> C} should not be possible (cf. Multiple Grammars and Partial Ordering).

5.3 The Rank-Ordering Model of EVAL (Coetzee 2004)

(85) Rank-Ordering Model of EVAL (ROE) (Coetzee 2004):
- (a) The constraint ranking within a language is a total order.
- (b) Candidates that survive past CUT-OFF are all accessible, but rank-ordered.
- (c) Several survivors give rise to (i) variation with relative preferences among variants; (ii) gradient word-likeness judgments.

(86) Example: *t,d*-deletion

INPUTS	OUTPUTS	*COMPLEX	ONSET	ALIGN-L-W	ALIGN-R-P	PARSE
cost us	(a) [cost][us]	*!	*			
	(b) → [cos]t[us]$_2$		*			*
	(c) → [cos][tus]$_1$			*		
cost me	(a) [cost][me]	*!				
	(b) → [cos]t[me]					*
	(c) [cos][tme]	*!		*		
cost	(a) [cost]	*!				
	(b) → [cos]t				*	*

(87) Input: /cost us/ /cost me/ /cost/
Outputs: [cos][tus]$_1$ [cos]t[me] [cos]t
[cos]t[us]$_2$

Decreasing well-formedness

(88) Prediction: No cumulative effects.

(89) This is different in the Multiple Grammars world. Consider a Partially Ordered Grammar *COMPLEX >> the rest: [*cos*]*t*[*us*] (= deletion) wins by 1/3 of the total rankings; [*cos*][*tus*] (= resyllabification) wins by 2/3 of the total rankings.

INPUTS	OUTPUTS	*COMPLEX	ONSET	ALIGN-L-W	ALIGN-R-P	PARSE
cost us	(a) [cost][us]	*!	*			
	(b) → [cos]t[us]		*			*
	(c) → [cos][tus]			*		
cost me	(a) [cost][me]	*!				
	(b) → [cos]t[me]					*
	(c) [cos][tme]	*!		*		
cost	(a) [cost]	*!				
	(b) → [cos]t				*	*

(90) An actual example: Finnish allomorph selection (Anttila 1997, 59). Constraints:
*H/I Avoid heavy syllables with a high vowel nucleus (high = *i, e*).
L.L No adjacent light (= CV) syllables.
*Í No stressed high vowels (high = *i*, *e*).

(91) *náa.pu.rèi.den* ~ *náa.pu.ri.en* 'neighbor-PL-GEN'

/naapuri/ + /-eiden/, /-ien/	*H/I	*L.L	*Í
(a) náa.pu.rèi.den = 37.2%	**		*
(b) náa.pu.ri.en = 62.8%	*	*	

(92) INTRA-CONTEXTUAL and INTER-CONTEXTUAL effects (Coetzee 2004:12-23):

		_C	_V	_##
Jamaican mesolect (Kingston)	*n*	1,252	793	252
(Patrick 1991:181)	% deleted	85	63	71

(a) Deletion is more common than retention within each context.
(b) Deletion is more common before consonants than vowels.

(93) Predicting intra-contextual quantitative effects in ROE (Coetzee 2004, 12-16):
*Ct#C No word-final [t,d] preceded by C and followed by C.
*Ct#V No word-final [t,d] preceded by C and followed by V.
MAX No *t,d*-deletion
Rankings vary across dialects.

(a) Jamaican English

		*Ct#C	*Ct#V	MAX
/Ct#C/	(a) $\varnothing_1$			*
	(b) t_2	*		
		*Ct#C	*Ct#V	MAX
/Ct#V/	(a) $\varnothing_1$			*
	(b) t_2		*	

(b) Tejano English

		*Ct#C	MAX	*Ct#V
/Ct#C/	(a) $\varnothing_1$		*	
	(b) t_2	*		
		*Ct#C	MAX	*Ct#V
/Ct#V/	(a) $\varnothing_2$		*	
	(b) t_1			*

(c) Neu data

		MAX	*Ct#C	*Ct#V
/Ct#C/	(a) $\varnothing_2$	*		
	(b) t_1		*	
		MAX	*Ct#C	*Ct#V
/Ct#V/	(a) $\varnothing_2$	*		
	(b) t_1			*

(94) Multiple Grammars capture intra-contextual effects in exactly the same way: different (sets of) rankings result in quantitative differences in the output.

(95) Predicting inter-contextual quantitative effects in ROE (Coetzee 2004, 16-17):
(a) Assume the fixed ranking: *Ct#C >> *Ct#V.
(b) Assume that EVAL can compare candidates across inputs.

		*Ct#C	*Ct#V	MAX
/Ct#C/	t	*		
		*Ct#C	*Ct#V	MAX
/Ct#V/	t		*	

Since *Ct#C >> *Ct#V, retention in _C is more marked than retention in _V.

(96) Response: Inter-contextual asymmetries follow from the t-order. Neither inherent rankings nor a special evaluation mode is necessary.

Appendix

T-Order Constructor was programmed by Curtis Andrus in the Python programming language during the Winter Quarter of 2006. The program can be downloaded from

http://www.stanford.edu/~anttila/research/torders/torder.zip
http://www.stanford.edu/~anttila/research/torders/t-order-manual.pdf

The current version of T-Order-Constructor reads factorial typology files produced by OTSoft (Hayes, Tesar, and Zuraw 2003). OTSoft can be downloaded from

http://www.linguistics.ucla.edu/people/hayes/otsoft/

T-Order Constructor requires Graphviz software to be installed in order to draw t-order graphs. More information on Graphviz software can be found at

http://www.graphviz.org/