Position paper
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The implications of typological evidence for formal grammar
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The implications of formal typological analysis for the investigation of typological evidence

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Typological evidence, in the sense of structured linguistic data describing linguistic variation, is the basis on which formal models of natural language typologies are constructed. On the other hand, formal models of typologies, with their often very detailed predictions, can contribute to the uncovering of structure in typological data, by encouraging research on so far neglected patterns. In this sense, there are implications of typological evidence for formal grammar, but there are also implications of formal grammar for the investigation of typological evidence. The relationship between the two lines of research is bidirectional and, if the risk of sterile opposition is avoided, may result in fruitful mutual influence, creating a positive loop where typological description informs formal typological analysis and formal typological analysis stimulates typological investigation.

The responsibilities of the two sides are different, though. Formal linguists must, first and foremost, reach a thorough understanding of the predictions and interpretations their models have to offer with respect to typological systems. Without reaching this understanding they cannot hope to contribute to the common typological endeavour.

In Optimality Theory (OT), linguistic structure is determined by violable, universal constraints, organized in language specific rankings. The logically possible orders of these constraint rankings generate the factorial typology, a set of abstract languages, which can then be compared to the typologies found among natural languages. In modern OT, these abstract typologies are generated computationally (here: with OT-Workplace, Prince, Tesar & Merchant 2007-2017) and investigated with advanced analytical tools.

An example for the mutual influence of typological evidence and formal typological analysis is the phenomenon of s-retraction (SR) in German and Italian dialects, as described in detail in the dialectological literature (Schmid 1956, Benware 1996). The example of s-retraction allows us to show that in OT we can (a) generate a model which is complete and clear in its predictions and thus can be compared to natural language typologies (b) identify those predictions for which typological evidence may still have to be forthcoming (c) offer a definition of the concept of minimal grammatical difference, characterizing subparts of this specific typology.

In s-retraction, an alveolar [s] is retracted to postalveolar [ʃ] before consonants. In the German dialects, this process took place step-by-step, involving always larger preconsonantal contexts (Benware 1996). A plausible chronology of the process in word-initial contexts runs as follows, with t_1 representing the initial stage, where only [sk] changes to [ʃk], and t_7 representing the final stage, where all preconsonantal contexts are affected:

(1)

t_1: s→ ʃ word-initially before	k
t_2:	k,p,t
t_3:	k,p,t,r
t_4:	k,p,t,r,l
t_5:	k,p,t,r,l,n
t_6:	k,p,t,r,l,n,m
t_7:	k,p,t,r,l,n,m,w

The dialectological literature (Hall&Scott 2007; Schmid 1956 for an overview) shows that s-retraction also progressed gradually with respect to word position: word-initially, the process took place earlier than word-medially. This effect is visible across the German dialect area, (see the map for *Schwester,* 'sister', in DiWA, map 247, König 2011: 150). We have therefore a second chronology of gradual change, derived from dialectal microvariation, in which t_0 is the stage without s-retraction, t_1 the stage with s-retraction only word-initially, and t_2 the stage with s-retraction before any consonant.

(2)

t_0: no SR	*swest* - North-West
t_1: word-initial SR	*schwest* - North-East, *Mitteldeutsch,* South-East
t_2: word-initial and word-medial SR	*schwescht* - South-West

Similar patterns occur in Italian dialects. Rohlfs (1949: 314, 442, see also the relevant AIS-maps) finds s-retraction in Southern Italian dialects which range from varieties where the process takes place before all consonants to those where it happens before velars and labials, to varieties with s-retraction before velars alone. We can again hypothesize a chronology of the process targeting an increasing number of places of articulation:

(3)

t_1:	s→ ʃ before	velars:	k	Marche
t_2:		velars, labials:	k, p, m	Napoletano, Cilento
t_3:		velars, labials, alveolars:	k, p, m, t, n, l	Northern Calabria, Sicily

Consider Napoletano (stage t2, where s s-retraction occurs before velars and labials, but not alveolars):

(4) SR in Napoletano: data from Ledgeway 2009: 99; Rohlfs: 442 and own data

word-initially		word-medially		place of articulation
ʃkale	'ladder'	ma**ʃk**atura	'patch'	velars
ʃpennere	'to spend'	ve**ʃp**era,	'wasp'	labials
stennere	'to spread out'	bi**sl**acco	'slack'	alveolars

From the descriptions of s-retraction therefore we infer that the phenomenon is (a) sensitive to the type of consonant following the sibilant and (b) sensitive to the position in the word (word-initial vs. word-medial contexts). These are the two empirical generalizations we will build our formal model on.

We can, first, develop a basic model of SR, by neglecting (b) and concentrating on a simplified version of (a) in which s-retraction takes place first before a certain set of consonants (let us take [t] as a representative of this set), then also before an additional set of consonants (let us take [n] as a representative).

We can assume that the following set of (potentially grammatical) candidates has to be evaluated by the constraints:

(5) Candidates, basic SR typology

	input		output	status
a.	/st/	→	[st]	no SR before t
b.	/st/	→	[ʃt]	SR before t
c.	/sn/	→	[sn]	no SR before n
d.	/sn/	→	[ʃn]	SR before n

These four candidates will be evaluated by the following set of constraints:

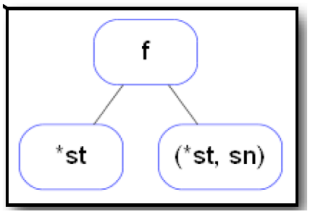
(6) Constraints, basic SR-typology

m.1	*{st}:	no [st] clusters
m.2	*{st, sn}:	no [st] or [sn] clusters
f		no unfaithful mapping /s/ → [ʃ]

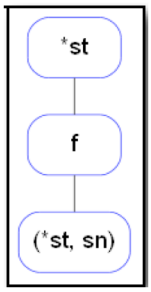
The two markedness constraints m.1 and m.2 favor s-retraction in certain contexts, by virtue of disfavoring [s] in those contexts. They are subset inclusion constraints in a stringency relation (Prince 1999) and can generate typologies where the effects of a markedness scale are visible (*st > *sn etc.). The faithfulness constraint f always militates against s-retraction.

OTWorkplace evaluates the candidates in (5) for all possible hierarchical orders of the constraints (rankings) and generates the grammars of abstract languages resulting from this evaluation.

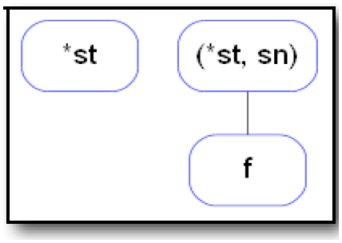
(7) Grammars of abstract languages, basic SR typology (generated by OTWorkplace)



a.
no s-retraction



b.
s-retraction before [t]



c.
full s-retraction before [t] and [n]

S-retraction occurs when one of the m-constraints, disfavoring /s+C/ clusters, dominates faithfulness, which demands no change. Thus:

- Language 7a: no SR because faithfulness dominates: st→st, sn→sn.
- Language 7b: SR before [t] because *st dominates: st→ʃt, sn→sn
- Language 7c: SR before [t] *and* [n] because *{st, sn} dominates: st→ʃt, sn→ʃn

The basic system predicts the existence of exactly three languages and no others. No language exists where s-retraction takes place before [n], *but not before* [t].

We thus have correctly predicted the fact observed in the dialectological literature, that SR involves increasingly larger sets of consonants, not random, single preconsonantal contexts. So far typological data and formal model agree - a welcome, though not very surprising result, given that the formal model is based on the typological data.

The computational model allows us to create models which exhibit realistic levels of complexity, advancing far beyond the simple example just presented. Thus, if we take into account three preconsonantal environments and the gradual involvement of word-initial, then word-medial contexts, the result is a typology of 10 abstract languages exhibiting various degrees of s-retraction, ranging from lg.1, with no s-retraction in any environment over languages such as lg.4, where s-retraction occurs only word-initially, to lg.10, where s-retraction takes place across the board:

(8) S-retraction: full typology of abstract languages (generated with OTWorkplace)

Input→	**aska**	**asla**	**asma**	**#ska**	**#sla**	**#sma**		
lg.1	sk	sl	sm	#sk	#sl	#sm	fully faithful	
lg.2	sk	sl	sm	#ʃk	#sl	#sm	only #_	#: C-1
lg.3	sk	sl	sm	#ʃk	#ʃl	#sm		#: C-1-2
lg.4	sk	sl	sm	#ʃk	#ʃl	#ʃm		#: C-1-2-3
lg.5	ʃk	sl	sm	#ʃk	#sl	#sm	medially: C-1	#: C-1
lg.6	ʃk	sl	sm	#ʃk	#ʃl	#sm		#: C-1-2
lg.7	ʃk	sl	sm	#ʃk	#ʃl	#ʃm		#: C-1-2-3
lg.8	ʃk	ʃl	sm	#ʃk	#ʃl	#sm	medially: C-1-2	#: C-1-2
lg.9	ʃk	ʃl	sm	#ʃk	#ʃl	#ʃm		#: C-1-2-3
lg.10	ʃk	ʃl	ʃm	#ʃk	#ʃl	#ʃm	medially: C-1-2-3	#: C-1-2-3

We can now conclude, that we have succeeded in fulfilling our promise (a), to generate a model which is complete and clear in its predictions and can be compared to natural language typologies.

This full model of SR furthermore makes the strong prediction that s-retraction *cannot target a larger set of contexts word-medially than word-initially*. This is a prediction which has not been in the focus of dialectological investigation so far, limited as it is to descriptions of the particular patterns observed in the families of German and Italian dialects, with rare dialogue between the two traditions of description (Schmid 1956). The formal model thus suggests that descriptions of SR should take into account this particular prediction and establish whether indeed it is borne out, in the dialects under investigation: is the set of preconsonantal contexts targeted by SR always equal or larger word-initially than word-medially? So far the dialectological literature has no answer to this question, since it has not been interested in it, but, if made aware, could produce descriptions with higher levels of adequacy and crosslinguistic comparability. We have thus succeeded in fulfilling promise (b), ie. to identify those predictions for which typological evidence still has to be forthcoming.

The sub-typologies of SR, as described by dialectologists for German and Italian, have the characteristic feature of gradual, minimal differentiation, a phenomenon often described in the dialectological literature. Diachronically, the phenomenon targets step-by-step always larger preconsonantal contexts. This gradual change is then often reflected synchronically in dialectal microvariation. The feature of minimal linguistic variation, evident in the data, can be found in the formal model of the typology as well, if the appropriate analytical tools are applied.

The notion of minimal difference between languages receives a precise definition once the Typlogical Properties of the formal model are extracted (Alber & Prince 2015, Alber & Prince, in prep., see also Alber, DelBusso & Prince 2016). We define Typological Properties as the ranking conditions necessary and sufficient to generate every language of a typological system. They thus form the inventory of ranking conditions which fully determine and classify a typology. Under our hypothesis, Typological Properties come with two values, one the logical opposite of the other.

The basic typology of s-retraction contains two Properties. The first (P.faith) distinguishes the faithful language, in which nothing happens, from those in which some change takes place. The second (P.SR) governs the extent of change.

(10) Properties of basic SR-typology

P.faith: f < > {m.1, m.2}			
	=	value A: f > m.1 and m.2	full faithfulness: 7a
		value B: m.1 or m.2 > f	some unfaithfulness: 7b, c
P.SR: m.2 < > f			
	=	value A: f > m.2	some resistance to SR: 7a, b
		value B: m.2 > f	full SR: 7c

Values A and B of each property are logical opposites of each other. This is obvious for P.SR, but it is true also for P.faith: if f has to dominate both m.1 and m.2 (value A), it cannot be the case that either m.1 or m.2 dominate f (value B).

The Property values of a formal typology define the grammars of the languages of the system. The three languages in (7) are classified according to Property values in (11). Every licit combination of values is represented. The absence of P.faith:A + P.SR:B follows from logic: f cannot dominate m.2 (P.faith:A) at the same time that m.2 dominates f (P.SR:B). Only logically consistent value sets define grammars.

(11) Classification of languages in basic SR-typology according to Property values

	7a: **no SR**	**7b**: **SR before [t]**	**7c: full SR**
P_1	**A** full faithfulness	**B** some unfaithfulness	**B** some unfaithfulness
P_2	**A** some resistance to SR	**A** some resistance to SR	**B** full SR

A pattern of minimal differences now emerges. The grammar of language 7a, with no s-retraction, is specified as (A,A). 7b, with s-retraction only before [t], is specified as (B, A). These differ *minimally*, in the sense that they differ in only one value. Similarly, the grammar of language 7b (B, A) differs minimally from that of 7c (B,B). Language 7a, however, is not minimally different from 7c, since the transition from (A,A) to (B,B) changes both values.

The notion of *minimal grammatical difference* can then be defined as follows:

(12) Minimally different: The grammars of two languages differ minimally if they differ in the smallest number of property values possible, in a typology.

This measure of minimal grammatical difference makes clear predictions as to what can be considered a legitimate gradual step in diachronic or synchronic variation: a minimal step relates two languages which differ minimally in property values.

Typological analysis yields impressively detailed results when applied to full-fledged typological systems. Thus, a typological analysis of the full typology of s-retraction in (8) yields six properties cross-classifying the system. Inside this matrix of property values we can identify the closest neighbors of each language, in terms of property values. There are five possible 'minimal paths' through the matrix, each a sequence of minimal stepwise changes.

Two of these paths correspond to the sequence of changes in the chronology of German and Southern Italian s-retraction in (1, 2, 3). In German varieties, s-retraction sees step-wise-involvement of always larger preconsonantal contexts in word-initial position, then expansion of s-retraction to word-medial contexts. In Romance varieties, s-retraction advances simultaneously both word-initially and word-medially:

(14) Paths of minial change in German (left) and Southern Italian varieties (right)

(B-values are indicators of SR; in P4-6, B-values indicate word-initial SR, in P1-3 word-medial SR)

	lg.1	lg.2	lg.3	lg.4	lg.7	lg.9	lg.10
P1	A	A	A	A	A	A	B
P2	A	A	A	A	A	B	B
P3	A	A	A	A	B	B	B
P4	A	A	A	B	B	B	B
P5	A	A	B	B	B	B	B
P6	A	B	B	B	B	B	B
	OHG/ Niederdt	att	att	MSG		Tyr	Móch

	lg.1	lg.2	lg.5	lg.6	lg.8	lg.9	lg.10
P1	A	A	A	A	A	A	B
P2	A	A	A	A	B	B	B
P3	A	A	B	B	B	B	B
P4	A	A	A	A	A	B	B
P5	A	A	A	B	B	B	B
P6	A	B	B	B	B	B	B
	prot.rom.		Marche		Nap.		NCal.

OHG = Old High German, Niederdt.=Niederdeutsch, att. = attested in historical documents, MSG = Modern Standard German, Tyr.= Tyrolean, Móch. = Mócheno, prot.rom = protoromance, Nap. = Napoletano, Ncal.= Northern Calabrian varieties.

We have now fulfilled promise (c), in offering, in terms of Property values, a definition of the concept of minimal grammatical difference, which is characteristic for subparts of this specific typology.

The example of s-retractions shows that formal typological analysis has important contributions to make to the investigation of linguistic typologies. It can generate typological models which, if complete and clear in their predictions, may be compared to the typological descriptions of natural languages. If detailed enough, these models may furthermore suggest the research of so far neglected typological evidence. Finally, at a higher level of typological analysis, the results of Property Analysis show that our formal models may penetrate to the core of general features of certain parts of a sub-typology, characterized as here by minimal grammatical differentiation.

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