On the Integration of Cumulative Effects into Optimality Theory*

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1 Introduction

The goal of this paper is to discuss the question of whether cumulative theories are indispensable, because they are needed in order to capture certain linguistic phenomena, or whether cumulative effects can be expressed equally well in an optimality-theoretic framework. If so, cumulative theories could be integrated into Optimality Theory (OT).

At first sight, the two theories seem to behave very differently. In OT, the number of violations of low-ranked constraints does not play any role as long as the constraint that is decisive for the outcome of the competition is higher-ranked. In a cumulative theory, on the other hand, the situation is somewhat different, because the underlying principle is that the weights of the involved factors are added up. Thus it can happen that some factors which individually do not have much weight and are therefore unimportant on their own become decisive as soon as they cooccur or appear repeatedly.

As empirical background I will use Pafel's cumulative approach to quantifier scope in German (cf. Pafel (1998)). I will discuss

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whether it is possible to "translate" it into OT, where the difficulties lie, and what kind of assumptions one might have to make. What I will not do is discuss Pafel's theory as such, that is, discuss whether it is able to capture the phenomenon of quantifier scope or where its advantages and disadvantages might lie; nor is the aim of this paper to provide an adequate optimality-theoretic account of quantifier scope in general (for this purpose see Heck (1999)). Pafel's theory only serves as a case study for a more theoretical debate; therefore, the approach itself as well as the judgments on the sentences are neither changed nor commented on.

2 Pafel's Approach to Quantifier Scope

Pafel introduces a number of factors that seem to have an impact on the scopal behavior of quantifiers, i.e., whether they tend to take wide scope over other quantifiers or not. Each factor is assigned some weight. In order to decide which one of two quantifiers in a given sentence tends to take wide scope, one has to determine which factors are relevant for each quantifier in the given context. Then one can calculate the scopal value (SV) of each quantifier by adding up the values of the relevant factors. The scopal behavior can then be determined from the difference between the scopal values as follows:

(i) $|SV(Q_1)-SV(Q_2)| \geq 1$:

The quantifier with the larger SV takes wide scope (i.e., the sentence is unambiguous).

(ii) $|SV(Q_1)-SV(Q_2)| < 1$:

Either quantifier may take wide scope (i.e., the sentence is ambiguous).

(a) $0 < |SV(Q_1)-SV(Q_2)| < 1$:

The reading in which the quantifier with the larger SV takes wide scope is preferred.

(b) $|SV(Q_1)-SV(Q_2)| = 0$:

Both readings are equally well available.[1]

The cumulative character of the approach is illustrated by the following four examples (Pafel's examples (3.17), (3.45), (3.42), (3.1)), in which the factors SUBJECT, EX-PRE (external precedence) and IN-DIS (inherent distributivity) are involved. These factors are defined as follows:

			weight:
EX-PRE	...	is assigned to quantifiers in the 'Vorfeld' which linearly precede other quantifiers;	1.5
SUBJECT	...	is assigned to subject quantifiers;	1
IN-DIS	...	is assigned to quantifiers that have an inherently distributive character.	1

[1]The distinction between (ii-a) and (ii-b) is only mentioned for completeness' sake. It does not play any role in the further discussion, since the question of how this difference can be expressed in an optimality-theoretic framework is not addressed here.

(1) Jeder Pianist hat eine Fuge in seinem Repertoire.
[every pianist]$_{nom}$ has [a fugue]$_{acc}$ in his repertoire

Q_1=jeder Pianist, Q_2=eine Fuge

Q_1: EX-PRE + SUBJECT + IN-DIS
Q_2: —

SV(Q_1)=1.5+1+1=3.5
SV(Q_2)=0

$Q_1 > Q_2$ (i.e., Q_1 has relative scope over Q_2): possible
$Q_2 > Q_1$ (i.e., Q_2 has relative scope over Q_1): impossible

(2) Jede Fuge hat ein Pianist in seinem Repertoire.
[every fugue]$_{acc}$ has [a pianist]$_{nom}$ in his repertoire

Q_1: EX-PRE + IN-DIS SV(Q_1)=1.5+1=2.5
Q_2: SUBJECT SV(Q_2)=1

$Q_1 > Q_2$: possible
$Q_2 > Q_1$: impossible

(3) Ein Pianist hat jede Fuge in seinem Repertoire.
[a pianist]$_{nom}$ has [every fugue]$_{acc}$ in his repertoire

Q_1: EX-PRE + SUBJECT SV(Q_1)=1.5+1=2.5
Q_2: IN-DIS SV(Q_2)=1

$Q_1 > Q_2$: possible
$Q_2 > Q_1$: impossible

(4) Eine Fuge hat jeder Pianist in seinem
[a fugue]$_{acc}$ has [every pianist]$_{nom}$ in his
Repertoire.
repertoire

Q_1: EX-PRE SV(Q_1)=1.5
Q_2: SUBJECT + IN-DIS SV(Q_2)=1+1=2

$Q_1 > Q_2$: possible
$Q_2 > Q_1$: possible

As these examples show, the scopal behavior of the quantifiers depends on the combination of the factors. Although, for instance, the factors SUBJECT and IN-DIS on their own do not indicate a general tendency to wide scope (cf. (2) and (3)), this can be the case if they cooccur (cf. example (4)).

3 The Translation into OT

What we need in order to establish an optimality-theoretic account of the data above are, informally speaking, candidates, constraints, and a constraint ranking; and if we try to show that OT can do the job as well as the cumulative theory, these have to be chosen in such a way that the results are equivalent to Pafel's results. Of course we cannot restrict ourselves to the four examples above, but for the beginning they already constitute a task and draw one's attention to the main problems.

Since in Pafel's theory relative quantifier scope only depends on the comparison of the involved quantifiers described in terms of a certain set of factors, and is not influenced by any further component like the syntactic derivation, the translation into OT might require some unconventional assumptions. The starting point is that we have two quantifiers with different properties, and based on this information alone our theory should be able to predict the possible scope relations. In analogy to Pafel's procedure I therefore propose that the quantifiers of the sentence under consideration constitute the candidate set and that the optimal candidate will be the quantifier which tends to take wide scope. In the case of ambiguous sentences this means that the candidates will have to be equally optimal.

As far as the constraints are concerned, it seems to be reasonable to adopt Pafel's factors and, as a first try, rank them according to their weight in Pafel's account such that constraints with greater weight are higher-ranked and constraints with the same weight are considered to be tied. With regard to the examples above we thus have the following constraints:

EX-PRE (E):	Quantifiers must occur in the ‘Vorfeld’ and precede some other quantifier.
SUBJECT (S):	Quantifiers must be subjects.
IN-DIS (I):	Quantifiers must be inherently distributive.

In order to get more plausible candidates than merely the quantifiers under consideration, one can alternatively use the sentences’ S-structures as input, which yields potential LFs as output. If it is assumed that the possibility for a quantifier to take wide scope is expressed by the fact that it precedes the other quantifier at LF, and if the constraints are reinterpreted in such a way that they refer to the first quantifier only (e.g., S: The first quantifier must be the subject), we get exactly the same results. The candidates in the tableaux are then to be understood as abbreviations for LF-representations in which the quantifier in question precedes the other quantifier.

Let’s see whether on these assumptions the predictions of Pafel’s approach can be captured.

(5) First ranking: $E \gg S \circ I$

(1)

Jeder	Pianist	hat	eine	Fuge	in seinem	Repertoire.
[every	pianist]$_{nom}$	has	[a	fugue]$_{acc}$	in his	repertoire

T_1:

	Candidates	E	S	I
⇒	Q_1: jeder Pianist			
	Q_2: eine Fuge	∗!	∗	∗

(2)

Jede	Fuge	hat	ein	Pianist	in seinem	Repertoire.
[every	fugue]$_{acc}$	has	[a	pianist]$_{nom}$	in his	repertoire

T_2:

	Candidates	E	S	I
⇒	Q_1: jede Fuge		*	
	Q_2: ein Pianist	*!		*

(3) Ein Pianist hat jede Fuge in seinem Repertoire.
[a pianist]$_{nom}$ has [every fugue]$_{acc}$ in his repertoire

T_3:

	Candidates	E	S	I
⇒	Q_1: ein Pianist			*
	Q_2: jede Fuge	*!	*	

(4) Eine Fuge hat jeder Pianist in seinem Rep.
[a fugue]$_{acc}$ has [every pianist]$_{nom}$ in his rep.

T_4:

	Candidates	E	S	I
⇒	Q_1: eine Fuge		*	*
*	Q_2: jeder Pianist	*!		

Unfortunately, this first approach does not work. Although the constraint ranking in (5) predicts the scopal behavior of the sentences (1)–(3) analogously to Pafel's theory (cf. T_1–T_3), it is not able to capture the ambiguity of example (4); cf. T_4.

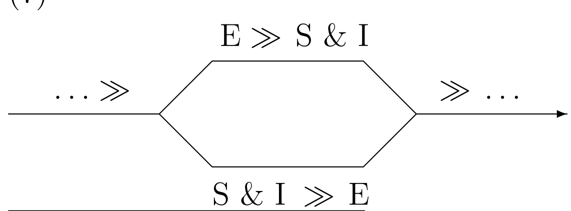
In order to predict this ambiguity, the two candidates in T_4 both have to be optimal, which means that in contrast to the situation in T_1–T_3, the violation of the constraint E in T_4 must not be fatal. If we compare the situation in T_4 with that in T_1–T_3, it can be concluded that it must be the simultaneous violation of the two low-ranked constraints S and I that prevents the E-violation of Q_2 from being fatal. At this point we are faced with an apparent contradiction. As mentioned in the introduction, it is a basic principle of OT that violations of low-ranked constraints cannot compensate for the violation of a higher-ranked constraint.

One way out of the dilemma would be to assume that there is a further constraint at work which renders the E-violation harmless, so to speak. And based on the results of T_1–T_4, a natural way to describe this constraint would be to say that it somehow combines the constraints S and I. Thus we might use the following local conjunction as a further constraint.[2] (As far as local conjunctions in general and in syntax in particular are concerned, cf. Smolensky (1995) and Legendre et al. (1998) respectively.)

(6) S & I: Quantifiers must be subjects or inherently distributive.

This constraint will be satisfied as long as at least one of the two constraints S or I is fulfilled, and it will be violated whenever S and I are simultaneously violated, which corresponds exactly to the situation in T_4 and distinguishes it from T_1–T_3. In order to derive the right result in T_4, we would like to say that E and S & I are tied. But since ties are not defined in a unified way, it has to be made explicit at this point what kind of ties we are talking about. Basically, we can draw a distinction between local and global ties (for a detailed analysis of different types of ties see Müller (1999a)). The main difference between these two concepts concerns the significance of violations of lower-ranked constraints. Under a local tie approach the prediction will be that these violations become relevant as soon as neither the tied constraints nor higher-ranked constraints decide the competition. Formally, this means that a given language is determined by one constraint ranking in which the tie is integrated as follows:

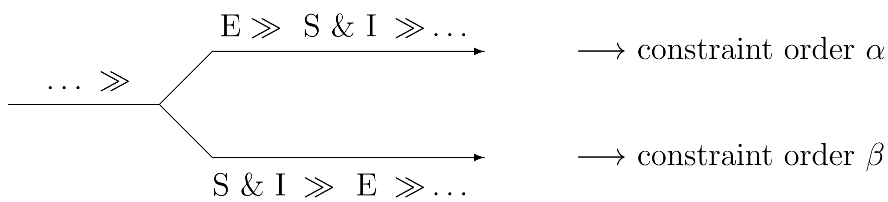
(7)



[2] If this constraint were translated back into Pafel's theory, it would correspond to a factor with the weight 2, since it involves both properties S (weight 1) and I (weight 1).

Under a global tie approach, on the other hand, a language is determined by a whole set of constraint rankings, namely those which result if every possible resolution of the tie is understood to be part of an independent order. This can be illustrated as in (8):

(8)



Optimality is then to be understood as optimality with regard to at least one of the resulting constraint orders. One consequence of this approach is that violations of constraints that are lower-ranked than the tie itself are irrelevant as long as there is at least one ranking under which the candidate is better than the competing ones.

If we assume that E and S & I are locally tied, we will not immediately get the right result for sentence (4), as T_5 shows.[3]

(4) Eine Fuge hat jeder Pianist in seinem Rep.
[a fugue]$_{acc}$ has [every pianist]$_{nom}$ in his rep.

T_5:

	Candidates	E	S & I	S	I
*	Q_1: eine Fuge		*	*!	*!
⇒	Q_2: jeder Pianist	*			

[3]The question might arise of whether it is legitimate to restrict the competition to the four constraints considered in T_5. It is true that there are higher-ranked constraints on which Q_1 and Q_2 differ, namely E & X and any local conjunction containing X and S or I, where X is a constraint that is violated by both candidates. However, the cumulative character of the constraints ensures that $(A \,\&\, X) \gg$ or $\circ$ $(B \,\&\, X) \Leftrightarrow A \gg$ or $\circ$ B. Thus, the outcome of a competition involving the constraints A & X, B & X, A, and B does not change if A & X and B & X are not taken into account.

In this case, Q_2 will win, because it does not violate the two low-ranked constraints S and I, in contrast to Q_1. For this approach to work, it would have to be assumed that the local conjunction X & Y ("X or Y must hold") somehow replaces the simple constraints X and Y, such that in a competition where X & Y is involved, X and Y must be excluded. (Intuitively it does not seem to be so unreasonable that one constraint should not be referred to twice, once in the form of X and the second time in the form of the local conjunction X & Y. For a related idea in which certain elements are only referred to once in determining the grammaticality of a given derivation, cf. Richards's (1998) Principle of Minimal Compliance.)

So if we replace T_5 with T_6, where S and I are excluded from the competition, and if we assume that E and S & I are locally tied, we finally get the right prediction for sentence (4):

T_6:

	Candidates	E	S & I
⇒	Q_1: eine Fuge		∗
⇒	Q_2: jeder Pianist	∗	

Alternatively, we could assume that the relation between the constraints E and S & I is expressed in terms of an ordered global tie (as illustrated in diagram (8)). With regard to sentence (4), this means that the tableau we would get would be equivalent to T_5, except that the violations of S and I would not be fatal and both quantifiers would be optimal: Q_1 under constraint order α and Q_2 under constraint order β.

T_7:

	Candidates	E	S & I	S	I
⇒	Q_1: eine Fuge		∗(!)	∗	∗
⇒	Q_2: jeder Pianist	∗(!)			

To sum up, the underlying ranking we have assumed so far is $E \circ S \,\&\, I \gg S \circ I$. However, the following example reveals that this order cannot be completely correct. In order to capture the ambiguity of sentence (9), which corresponds to Pafel's example (3.108b), E and S have to be tied.

(9) Eine Fuge haben einige Pianisten in ihrem Rep.
[a fugue]$_{acc}$ have [some pianists]$_{nom}$ in their rep.

Q_1:	EX-PRE	$SV(Q_1)=1.5$
Q_2:	SUBJECT	$SV(Q_2)=1$

$Q_1 > Q_2$: possible
$Q_2 > Q_1$: possible

T_8:

	Candidates	E	S
⇒	Q_1: eine Fuge		$*$
⇒	Q_2: einige Pianisten	$*$	

This observation raises a severe problem. If we assume on the one hand that E is tied with S (and also with I, as the difference between the scopal values shows), and on the other hand that E is tied with S & I, we have to conclude that S & I is also tied with S and I because of transitivity. But if we consider these constraints in the light of Pafel's approach,[4] they correspond to factors with the weights 2 and 1 respectively, which means that the difference is ≥ 1. Thus only the factor with the greater weight should be able to take wide scope, and the corresponding constraint should be higher-ranked than the other one. So it must be concluded that we face a problem with regard to transitivity.

[4]It is not possible to provide a concrete example that only involves the two constraints S & I and S or I. These combinations are ruled out, because Pafel's postulation of the two contrasting factors EX-PRE and IN-PRE assures that one of them is always involved. (The latter property is assigned to quantifiers in the 'Mittelfeld' that linearly precede other quantifiers.) But I think the general problem becomes clear nevertheless.

4 The Transitivity Problem

As far as the examples (1)–(4) are concerned, it seems to be possible to derive the predictions of Pafel's cumulative theory (CT) by means of an optimality-theoretic analysis somehow. However, there is one essential difference between the two theories, which probably constitutes the main difficulty for the integration of cumulative effects into OT. If we compare the behavior of two quantifiers in Pafel's theory, there are three possible results: The absolute value of the difference between the scopal values might be ≥ 1, $= 0$, or $\in\,]\,0, 1[$. In OT, on the other hand, we basically have two possibilities to describe the relation between two constraints. One can be higher-ranked than the other, or they can be tied. As mentioned before, it seems to be reasonable to assume the following "translation rules" (where A and B are factors relevant for scope, W(X):= the weight of factor X, and Con(X):= the constraint derived from factor X):

(i)	W(A)=W(B)	$\longrightarrow$	Con(A) $\circ$ Con(B)
(ii)	W(A)$-$W(B) ≥ 1	$\longrightarrow$	Con(A) $\gg$ Con(B)

However, the third possibility, where $0<|\mathrm{W(A)}-\mathrm{W(B)}|<1$, is problematic. On the one hand, this configuration predicts ambiguity, thus the corresponding constraints cannot be ranked in a dominance relation. But if they are tied, we have a problem with transitivity, as was already observed at the end of the last section. Consider the following configuration:

SV(Q_1)=2	involved factor: A
SV(Q_2)=1.5	involved factor: B
SV(Q_3)=1	involved factor: C

CT:	(a)	$SV(Q_1) - SV(Q_2) = 0.5$	$\longrightarrow$	predicts ambiguity
	(b)	$SV(Q_2) - SV(Q_3) = 0.5$	$\longrightarrow$	predicts ambiguity
but:	(c)	$SV(Q_1) - SV(Q_3) = 1$	$\longrightarrow$	predicts no ambiguity

OT: According to the result in (a), one would like to say that $A \circ B$; but according to the result in (b), one would like to say that $B \circ C$.

$\longrightarrow$ Because of transitivity, we would have to assume $A \circ C$. This contradicts the result in (c), according to which we would expect that $A \gg C$.

So if we assumed a strict transitive order, the consequence would be that all factors belonging to the set T_F would translate into tied constraints, where T_F is defined as the set containing the factor F and all those factors whose weights are less than 1 step away from the weight of an element belonging to T_F. This domino effect would render most of the constraints equally strong and lead to false predictions, as the following example illustrates. This example (Pafel's number 3.104) contains a new factor, SL-PAT, which is assigned to quantifiers with a slight tendency to be interpreted as Patients. It has the weight 1 and translates into the constraint SL, which says that quantifiers must have a slight tendency to be interpreted as Patients.

(10) Einem Kind hat er jedes Märchen erzählt.
[a child]$_{dat}$ has [he]$_{nom}$ [every fairytale]$_{acc}$ told

Q_1: EX-PRE + SL-PAT $\quad$ $SV(Q_1)=1.5+1=2.5$
Q_2: IN-DIS $\quad$ $SV(Q_2)=1$

$Q_1 > Q_2$: possible
$Q_2 > Q_1$: impossible

Starting with the difference in weight between the two factors E and I, which is $1.5-1=0.5$, we can assume that $E \circ I$. Similarly, from the difference between the weights associated with E and

SL & I, which is 2−1.5=0.5, we can conclude that E ∘ SL & I; so according to transitivity we get the relation I ∘ SL & I. On the other hand, SL & I is tied with E & SL, since the relevant difference is 2.5−2=0.5. Again because of transitivity, we therefore get the result that I ∘ E & SL. But as illustrated in T_9, this gives us the wrong predictions with regard to sentence (10), in which only the first quantifier can take wide scope.

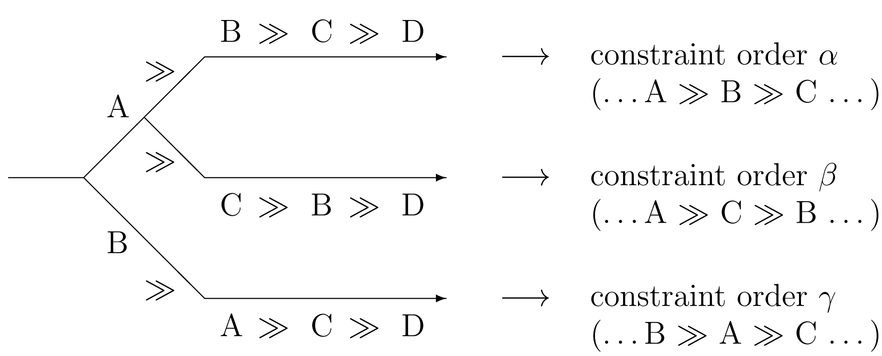
T_9:

		Candidates	E & SL	I
	⇒	Q_1: einem Kind		∗
*	⇒	Q_2: jedes Märchen	∗	

If we want to make sure that only Q_1 wins, E & SL must be ranked higher than I, a ranking which is also suggested by the difference between their corresponding weights, which is 2.5−1=1.5.

I do not know how to solve this problem without giving up to some extent the idea that constraint orders must be strictly transitive. But if we allow that A ∘ B and B ∘ C does not necessarily imply A ∘ C, we can account for the examples above with the following diagram:

(11)



In (11), two global ties are involved, which express the relations A ∘ B and B ∘ C, but still all three resulting constraint orders predict that A is higher-ranked than C. This is possible because in contrast to usual assumptions, according to which the branches of global ties are continued in the same way, the second tie in (11) does not affect all branches, but is only part of the two constraint orders α and β. So we could propose that the occurrence of global ties need not necessarily affect all branches of the ranking structure. With this assumption the transitivity problem can be solved, which means that the idea of strict transitivity in constraint rankings must be given up (and this might be a controversial result). However, transitivity does not have to be given up completely, since each constraint order in itself remains transitive. It seems to me that this is the easiest way to integrate the non-transitive effects of cumulative theories into OT.[5]

The question then arises of how the underlying relation between the constraints A, B, and C, which is illustrated in (11), can be formally expressed. Following a suggestion by Ralf Vogel (p.c.), I propose that it can be captured adequately by the relation (A $\gg$ C) $\circ$ B, where this kind of interaction between ties and hierarchical rankings is defined as follows:

(12)

$$\begin{array}{lclcl}
(\mathrm{A} \gg \mathrm{C}) \circ \mathrm{B} & := & \mathrm{A} \circ \mathrm{B} \gg \mathrm{C} & \vee & \mathrm{A} \gg \mathrm{C} \circ \mathrm{B} \\
 & = & \mathrm{A} \gg \mathrm{B} \gg \mathrm{C} & \vee & \mathrm{B} \gg \mathrm{A} \gg \mathrm{C} \\
 & & \vee \;\; \mathrm{A} \gg \mathrm{C} \gg \mathrm{B} & (\vee & \mathrm{A} \gg \mathrm{B} \gg \mathrm{C})
\end{array}$$

resulting constraint orders:

(i) A $\gg$ B $\gg$ C
(ii) B $\gg$ A $\gg$ C
(iii) A $\gg$ C $\gg$ B

This definition can be generalized in such a way that it can be applied to all sorts of combinations between ties and (bracketed) asymmetric rankings. The crucial point is that the brackets on hierarchical rankings make it possible to preserve this hierarchy even in a tied order. This means that if the tie is resolved, it will yield only those combinations possible between the tied elements

[5] The situation in which A $\circ$ B and B $\circ$ C, but C $\gg$ A must be excluded, is not as unusual as it may seem at first sight. It also occurs, for example, in Müller (1999b), where it is assumed on the one hand (by transitivity) that A $\circ$ C, but where on the other hand C $\gg$ A is excluded because of an underlying meta-constraint which says that A must be higher-ranked than C.

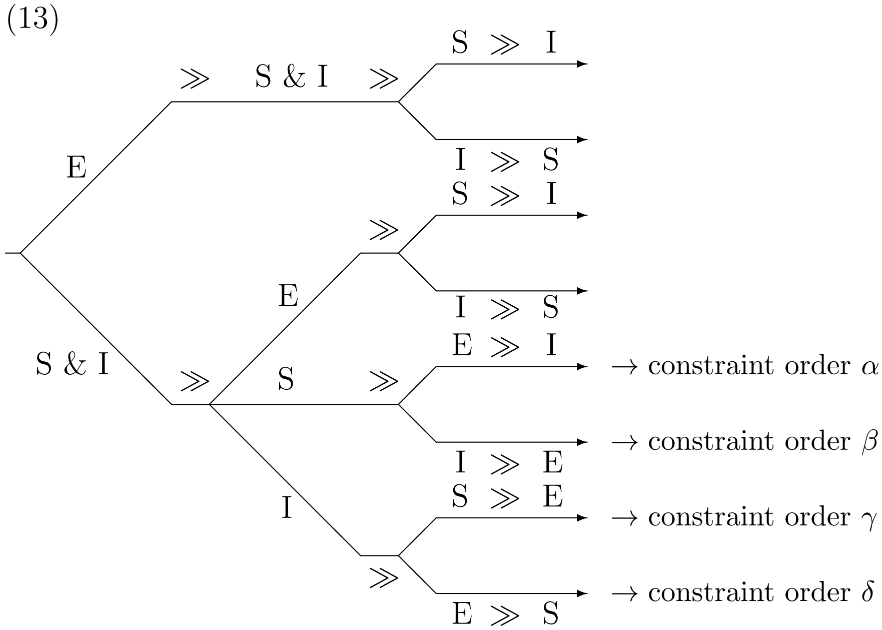
in which the hierarchy indicated in brackets is preserved.

5 Combining Constraints

In section 3 we considered four sentences that involved the simple constraints E, S, and I. In order to account for the behavior of the quantifiers in these examples, the additional constraint S & I was introduced. But what about constraints like E & S, E & I, or E & S & I? The question that needs to be discussed at this point is what kind of constraint combinations have to be taken into account. Since quantifiers can exhibit all sorts of combined properties, the answer should be that in principle all constraint combinations have to be considered. However, if we examined quantifiers with n different properties, we would have to discuss $2^n - 1$ constraints. Since the first four sentences have already shown that a certain subset of all constraints seems to suffice to determine the outcome of the competition for a concrete example, it would be helpful to find out what this subset has to look like.

Remember that the last observation in section 3 was that E must not only be tied with S & I, but also with S and I, whereas S & I is higher-ranked than S and I, giving rise to the transitivity problem. In the light of the previous section, we can now assume that the underlying formal relation is (S & I $\gg$ S $\circ$ I) $\circ$ E, which is illustrated by the diagram in (13) (cf. also the calculation in the appendix).

(13)



This constraint ranking is indeed able to predict the ambiguity of sentence (4)[6] (cf. T_{10}). But if the competition is restricted to the same set of constraints (i.e., {S & I, E, S, I}), it does not make the correct predictions for the unambiguous sentences (2) and (3), in which only the first quantifier can take wide scope (cf. T_{11} and T_{12}).

(4)	Eine	Fuge	hat jeder	Pianist	in seinem	Rep.
	[a	fugue]$_{acc}$	has [every	pianist]$_{nom}$	in his	rep.

T_{10}:

	Candidates	S & I	E	S	I
⇒	Q_1: eine Fuge	∗(!)		∗	∗
⇒	Q_2: jeder Pianist		∗(!)		

(2)	Jede	Fuge	hat ein	Pianist	in seinem	Repertoire.
	[every	fugue]$_{acc}$	has [a	pianist]$_{nom}$	in his	repertoire

[6]The dotted lines in the tableaux indicate that two neighboring constraints X and Y are tied, but that their corresponding weights are not equal.

T_{11}:

		Candidates	S & I	E	S	I
	⇒	Q_1: jede Fuge			∗(!)	
*	⇒	Q_2: ein Pianist		∗(!)		∗(!)

(3) Ein Pianist hat jede Fuge in seinem Repertoire.
[a pianist]$_{nom}$ has [every fugue]$_{acc}$ in his repertoire

T_{12}:

		Candidates	S & I	E	S	I
	⇒	Q_1: ein Pianist				∗(!)
*	⇒	Q_2: jede Fuge		∗(!)	∗(!)	

According to structure (13), not only Q_1 but also Q_2 is optimal in both tableaux, namely under the constraint orders α and β in the case of T_{11}, and under the constraint orders γ and δ in the case of T_{12}. The conclusion that can be drawn is that the constraint subset relevant for the examples (2) and (3) has not been completely taken into consideration in T_{11} and T_{12}. Based on our observations concerning sentence (4), it seems reasonable to assume that the relevant subset CON_{rel} (i.e., the smallest set of constraints to which the competition can be reduced) consists of two members only, namely the combinations of the constraints derived from the properties of each quantifier. As far as the examples (2) and (3) are concerned, this means that the relevant constraint subsets are {E & I, S} and {E & S, I} respectively (cf. T_{13} and T_{14}).

T_{13}:

	Candidates	E & I	S
⇒	Q_1: jede Fuge		∗
	Q_2: ein Pianist	∗!	

T_{14}:

	Candidates	E & S	I
⇒	Q_1: ein Pianist		∗
	Q_2: jede Fuge	∗!	

The following example[7] serves as a further illustration of this generalization concerning CON_{rel}. It contains two new factors: ST-L-DB refers to strong lexical discourse binding and has the weight 2; FOCUS is assigned to focused quantifiers[8] and has the weight -1. These factors translate into the following two constraints:

ST-L-DB (ST):	Quantifiers must occur in strong lexical discourse binding contexts.
FOCUS (F):	Quantifiers must be focused.

(14)

Welche Fuge	hat	jeder Pianist	in seinem	Rep.?
[which fugue]$_{acc}$	has	[every pianist]$_{nom}$	in his	rep.

Q_1: EX-PRE + ST-L-DB + FOCUS
Q_2: SUBJECT + IN-DIS

$SV(Q_1)=1.5+2-1=2.5$
$SV(Q_2)=1+1=2$

$Q_1 > Q_2$: possible
$Q_2 > Q_1$: possible

relevant constraint subset: {E & ST & F, S & I} $\subseteq$ CON, where CON is the set comprising all constraint combinations

constraint ranking: E & ST & F $\circ$ S & I

T_{15}:

	Candidates	E & ST & F	S & I
⇒	Q_1: welche Fuge		$*$
⇒	Q_2: jeder Pianist	$*$	

[7] The sentences (14) and (15) correspond to Pafel's examples (3.164') and (3.165).

[8] Pafel assumes that *wh*-phrases are inherently focused (cf. Pafel (1998:98)).

However, sentences in which the quantifiers share some common properties relevant for scope require a slight modification to the definition of CON_{rel}. Since neither candidate would violate a constraint derived from (one of) these properties, these constraints are irrelevant for the competition and must therefore be excluded from CON_{rel}. Thus, CON_{rel} can be defined as follows: The first element of CON_{rel} is the local conjunction that involves the constraints derived from Q_1's properties minus those Q_1 shares with Q_2, and the second element combines the constraints derived from Q_2's properties minus those shared with Q_1. Example (15) serves as an illustration. While constraint subset (i) does not yield the correct result (cf. $T_{16(i)}$), constraint subset (ii), which consists of the same constraint combinations except that the common property F is excluded, makes the correct predictions (cf. $T_{16(ii)}$).

(15) Welche Fuge hat JEder Pianist gespielt?
[which fugue]$_{acc}$ has [EVery pianist]$_{nom}$ played

Q_1: EX-PRE + ST-L-DB + FOCUS
Q_2: SUBJECT + IN-DIS + FOCUS

$SV(Q_1)=1.5+2-1=2.5$
$SV(Q_2)=1+1-1=1$

$Q_1 > Q_2$: possible
$Q_2 > Q_1$: impossible

relevant constraint subset: (i) {E & ST & F, S & I & F}
(ii) {E & ST, S & I }

constraint ranking: (i) E & ST & F $\gg$ S & I & F
(ii) E & ST $\gg$ S & I

$T_{16(i)}$:

	Candidates	E & ST & F	S & I & F
	⇒ Q_1: welche Fuge		
*	⇒ Q_2: JEder Pianist		

$T_{16(ii)}$:

	Candidates	E & ST	S & I
⇒	Q_1: welche Fuge		$*$
	Q_2: JEder Pianist	$*!$	

As far as factors with negative weight are concerned, one might alternatively translate them into negative constraints in order to avoid configurations where X $\gg$ X & Y, which contradicts the definition of local conjunction. The factor FOCUS, for example, would then translate into the following constraint:

*F: Quantifiers must not be focused.

In fact, we could then also try to replace the factor FOCUS (with weight -1), which is associated with focused quantifiers, with a factor *FOCUS with weight 1, which is associated with unfocused quantifiers. In this way we could generally reinterpret factors with negative weight such that they would all be assigned positive weight. With regard to example (14), we would then have the following configuration, which illustrates that the difference between the scopal values and therefore the predictions on possible scope relations remain unaffected by this reinterpretation.

(14') Welche Fuge hat jeder Pianist in seinem Rep.?
[which fugue]$_{acc}$ has [every pianist]$_{nom}$ in his rep.

Q_1: EX-PRE + ST-L-DB
Q_2: SUBJECT + IN-DIS + *FOCUS

SV(Q_1)=1.5+2=3.5
SV(Q_2)=1+1+1=3

$Q_1 > Q_2$: possible
$Q_2 > Q_1$: possible

relevant constraint subset: {E & ST, S & I & *F}

constraint ranking: E & ST ∘ S & I & *F

T_{17}:

	Candidates	E & ST	S & I & *F
⇒	Q_1: welche Fuge		∗
⇒	Q_2: jeder Pianist	∗	

As far as example (15) is concerned, the factor *FOCUS would not be involved at all, because both quantifiers in the sentence are focused. Hence, *F would not belong to the relevant constraint subset. However, all sentences that contain unfocused quantifiers (like the examples (1)-(4)) are now associated with the factor *FOCUS and therefore with the constraint *F; but as our considerations above have shown, *F will be excluded from CON_{rel} in case *both* involved quantifiers are unfocused. Thus the replacement of F/FOCUS by *F/*FOCUS does not affect our earlier examples.

Finally, there is another configuration in Pafel's approach that must be mentioned. If a quantifier is not associated with any property that is relevant for scope, it receives the scopal value 0. Thus it is possible for a sentence containing such a quantifier to be ambiguous in case the second quantifier Q_2 has a scopal value with $-1 < SV(Q_2) < 1$. Assume that Q_2 has the property A, which translates into the constraint A. As indicated in T_{18}, Q_2 fulfils A in contrast to Q_1. Thus we are faced with the situation that Q_2 will always win if we do not introduce a further constraint which is violated by Q_2 but not by Q_1.

T_{18}:

	Candidates	A
∗	Q_1	∗!
⇒	Q_2	

In order to get the right result, we have to think of an additional constraint which is satisfied exactly by those quantifiers which do not have any properties that influence the quantifier's scopal behavior. Such a constraint might look as follows:

NO PROPERTY (N-PR):
Quantifiers must not have properties relevant for scope.

On this assumption, the competition works as follows:

(16) Q_1: — $\quad SV(Q_1)=0$
Q_2: A $\quad -1 < SV(Q_2) < 1$

$Q_1 > Q_2$: possible
$Q_2 > Q_1$: possible

relevant constraint subset: {N-PR, A}

constraint ranking: N-PR $\circ$ A

T_{19}:

	Candidates	A	N-PR
⇒	Q_1	*	
⇒	Q_2		*

Note that the constraint N-PR must also come into play if a quantifier shares all its properties with the second quantifier of the sentence. This configuration is illustrated in the following example, where A and B are properties relevant for scope that translate into the constraints A and B respectively.

(17) Q_1: A + B
Q_2: A, where $|SV(Q_1)-SV(Q_2)| < 1$,
i.e., either quantifier can take wide scope.

As discussed above, the constraint derived from the common property A is excluded from CON_{rel}. Thus the relevant constraint subset might be:

(i) {B}, or
(ii) {B, N-PR}.

For (ii), the constraint ranking is B $\circ$ N-PR, because we know from our assumptions in (17) that |weight(B)|< 1. The results we get for (i) and (ii) are illustrated in $T_{20(i)}$ and $T_{20(ii)}$, which show that we have to use the second constraint subset.

$T_{20(i)}$:

	Candidates	B
⇒	Q_1	
*	Q_2	*!

$T_{20(ii)}$:

	Candidates	B	N-PR
⇒	Q_1		*
⇒	Q_2	*	

One further situation that can occur in cumulative theories, which we do not find in Pafel's approach however, is that the cumulative occurrence of one and the same constraint violation might change the outcome of the whole competition. Imagine the following configuration:

T_{21}:

	Candidates	A	B
	C_1	*!	
⇒	C_2		*

T_{22}:

	Candidates	A	B
⇒	C_1	*	
	C_2		**!

If it is assumed that A $\gg$ B, we can account for T_{21}, but not for

T_{22}, and if we assume that B $\gg$ A, we get the right prediction for T_{22}, but not for T_{21}. In the light of the ongoing discussion, one way out of the dilemma might be to assume that constraint combinations of the sort X & Y are not only possible in case X $\neq$ Y, but also if X = Y. The resulting constraint would be a reflexive local conjunction (cf. also Legendre et al. (1998)), which would have to be interpreted as follows:

(18) (i) The constraint X & X =: X^2 is violated iff X is violated twice;

(ii) *more general:*
The constraint X^n is violated iff X is violated n times.

On these assumptions, T_{21} and T_{22} can be accounted for with the following constraint ranking: $B^2 \gg A \gg B$. Since $A \gg B$, C_2 wins in T_{21}, and since $B^2 \gg A$, C_1 wins in T_{22}, as illustrated more precisely in T_{23}.

T_{23}:

	Candidates	B^2	A
$\Rightarrow$	C_1		$*$
	C_2	$*!$	

6 Conclusion

As the discussion showed, it seems to be possible to integrate cumulative effects, as they occur, for example, in Pafel's approach to quantifier scope, into OT if some special assumptions are accepted. In order to get effective constraints, it was first of all necessary to introduce (reflexive) local conjunction, which multiplies the number of constraints enormously and might therefore give rise to criticism. But as could be shown in the previous section, the outcome of the competition only hinges on a small subset of the whole set of constraints.

A much more severe problem was approached in section 4 and concerns the transitivity of constraint rankings. Since in cumulative theories, transitivity does not need to hold, we face the problem that we might have to integrate non-transitive effects into a transitive order. I think that this is only possible if the idea of strict or global transitivity, where A $\circ$ B and B $\circ$ C necessarily implies A $\circ$ C, is given up. Thus, I proposed that the occurrence of global ties within global ties might only affect some of the branches. This approach allows on the one hand the integration of non-transitive effects, but preserves on the other hand at least locally the transitive order, because each resulting constraint order remains transitive. Thus, this step is not as radical as it might seem at first sight. Of course, it has to be pointed out that global ties in general increase the amount of complexity tremendously; however the number of the resulting constraint rankings is again reduced somewhat if global ties do not necessarily have to affect all branches. As far as the formal realization of this relation is concerned, it can be expressed as interaction between ties and bracketed hierarchical rankings. This seems to me to be a natural elaboration of the two basic relations "$\gg$" and "$\circ$", which is to some extent reminiscent of the interaction between addition and multiplication.

Finally, the question arose as to how CON_{rel}, the smallest set of constraints relevant for a competition, can be defined. It is clear that constraints on which the candidates behave alike can be excluded and that furthermore simple constraints which are also part of relevant local conjunctions need not be taken into consideration. (In the latter case, the simple constraints will not be decisive, since the corresponding local conjunctions are higher-ranked.) Moreover, the cumulative character of the constraints ensures that (A & X) $\gg$ or $\circ$ (B & X) $\Leftrightarrow$ A $\gg$ or $\circ$ B, which allows us to ignore certain higher-ranked local conjunctions on which the candidates differ. As far as the integration of Pafel's approach into OT is concerned, it could therefore be concluded that CON_{rel} contains only two constraints, namely the constraint combinations derived from the properties associated with each quantifier.

There are two questions I have not addressed here. First, it could be asked whether anything would change if CON_{rel} contained more than two constraints or if more than two candidates were involved. The second question concerns the representation of tendencies in OT, as for example the preference for certain readings. One possibility might be that it can somehow be captured by the number of constraint orders which are affected by certain ties, since this is exactly how ambiguities predicted by the relation $0 < |\mathrm{SV}(\mathrm{Q}_1) - \mathrm{SV}(\mathrm{Q}_2)| < 1$ are characterized. However, whether this approach would really work would have to be discussed in more detail.

Appendix

The ranking we finally assumed for the constraints S & I, S, I, and E was (S & I $\gg$ S $\circ$ I) $\circ$ E, which results in eight constraint orders if the ties are resolved (cf. diagram (13)). This outcome can be predicted very easily if we assume the following definition, which is a generalization of definition (12):

Generalization of definition (12):

$$
\begin{array}{rcl}
(\mathrm{A}_1 \gg \ldots \gg \mathrm{A}_n) \circ \mathrm{B} & := & \mathrm{A}_1 \circ \mathrm{B} \gg \mathrm{A}_2 \gg \mathrm{A}_3 \gg \ldots \gg \mathrm{A}_n \\
 & \vee & \mathrm{A}_1 \gg \mathrm{A}_2 \circ \mathrm{B} \gg \mathrm{A}_3 \gg \ldots \gg \mathrm{A}_n \\
 & \vee & \ldots \\
 & \vee & \mathrm{A}_1 \gg \mathrm{A}_2 \gg \mathrm{A}_3 \gg \ldots \gg \mathrm{A}_n \circ \mathrm{B}
\end{array}
$$

Example: (D $\gg$ A $\circ$ B) $\circ$ C

This is the underlying formal relation if A $\circ$ B, A $\circ$ C, B $\circ$ C, D $\circ$ C, but D $\gg$ A and D $\gg$ B. If we apply the definition above, we get the following result:

$$
\begin{array}{rlcl}
 & (D \gg A \circ B) \circ C & & \\
= & (D \gg A \gg B) \circ C & \vee & (D \gg B \gg A) \circ C \\
= & D \circ C \gg A \gg B & \vee & D \circ C \gg B \gg A \\
\vee & D \gg A \circ C \gg B & \vee & D \gg B \circ C \gg A \\
\vee & D \gg A \gg B \circ C & \vee & D \gg B \gg A \circ C \\
= & D \gg C \gg A \gg B & \vee & D \gg C \gg B \gg A \\
\vee & C \gg D \gg A \gg B & \vee & C \gg D \gg B \gg A \\
\vee & D \gg A \gg C \gg B & \vee & D \gg B \gg C \gg A \\
(\vee & D \gg C \gg A \gg B & \vee & D \gg C \gg B \gg A) \\
\vee & D \gg A \gg B \gg C & \vee & D \gg B \gg A \gg C \\
(\vee & D \gg A \gg C \gg B & \vee & D \gg B \gg C \gg A)
\end{array}
$$

resulting constraint orders:

(i)	$C \gg D \gg A \gg B$
(ii)	$C \gg D \gg B \gg A$
(iii)	$D \gg A \gg B \gg C$
(iv)	$D \gg A \gg C \gg B$
(v)	$D \gg B \gg A \gg C$
(vi)	$D \gg B \gg C \gg A$
(vii)	$D \gg C \gg A \gg B$
(viii)	$D \gg C \gg B \gg A$

References

Heck, Fabian. 1999. Quantifier Scope in German and Cyclic Optimisation. Ms., Universität Stuttgart.

Legendre, Géraldine, Paul Smolensky & Colin Wilson. 1998. When is Less More? Faithfulness and Minimal Links in Wh-Chains. In *Is the Best Good Enough?*, eds Pilar Barbosa et al., 249-289. Cambridge, Mass.: MIT Press & MITWPL.

Müller, Gereon. 1999a. Optimality-Theoretic Syntax. Distributed at LOT Summerschool, Universität Potsdam.

Müller, Gereon. 1999b. Das Pronominaladverb als Reparaturphänomen. Submitted to Linguistische Berichte. (Ms., Universität Tübingen.)

Pafel, Jürgen. 1998. Skopus und logische Struktur. Studien zum Quantorenskopus im Deutschen. Technical Report 129, Arbeitspapiere des SfB 340. Universität Tübingen.

Prince, Alan & Paul Smolensky. 1993. *Optimality Theory. Constraint Interaction in Generative Grammar.* Ms., Rutgers University & University of Colorado, Boulder. To appear as LI Monograph: Cambridge, Mass.: MIT Press.

Richards, Norvin. 1998. The Principle of Minimal Compliance. *Linguistic Inquiry* 29: 599-629.

Smolensky, Paul. 1995. On the Internal Structure of Con, the Constraint Component of UG. Ms., Johns Hopkins University.