Rule flipping and the feeding-bleeding relationship

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Abstract

In this paper, we discuss the relationship that holds between feeding and bleeding in the interaction of rules. Whereas it is presently well understood how to change, for example, a feeding relation into one of counterfeeding (i.e. by reversing the order of application), the transformation from feeding to bleeding is still unclear. We show that there is a systematic way to go from feeding to bleeding and *vice versa* by means of 'flipping' rules (reversing the input and output). The ensuing discussion uncovers more about the nature of rules in general and opens up a wealth of further analytical possibilities.

1. Introduction

In the discussion of grammatical rules, much attention has been paid (especially in phonology) to the interaction of rules. Generally, if there is an interaction between two rules it may vary along two dimensions

1. Chronology (with the two values *timely* vs. *tardy*) and
2. Interference (with the two values *non-inhibitory* vs. *non-excitatory*)

whose cross-classification gives the familiar four types of rule-interaction in (1) first discussed by Kiparsky (1968).

(1) *Types of rule-interaction*[1]

		Chronology	
		timely	*tardy*
Interference	*non-inhibitory*	feeding	counterbleeding
	non-excitatory	bleeding	counterfeeding

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[1]We refrain from using the more common terms *transparent* for feeding and bleeding and

Rule A interacts with another rule B in a timely manner if the application of rule A affects the application of rule B. It interacts in a tardy manner if it applies too late to have an effect. This effect can be either excitatory, when application of rule A makes the application of rule B possible, or inhibitory, when it makes it impossible.

Whereas it is particularly well understood how alternations between timely and tardy interactions (e.g. feeding vs. counterfeeding) can be achieved (by reversing the order of application of two rules), little or nothing has been said about alternations between excitatory and inhibitory (feeding vs. bleeding), and non-inhibitory and non-excitatory interactions (counterbleeding vs. counterfeeding). The present paper is an attempt at bridging this gap by discussing some observations about the internal structure of rules and how it is possible to turn a feeding interaction into a bleeding interaction.

Let us begin with the following real-world example: Imagine you are standing in a lift and the doors are closing. You see a good friend approaching the lift. He is great company and you enjoy your shared lift-rides. To your right are two buttons: One opens the doors, and the other closes them. It is obvious that your friend can only enter the lift if the doors are open, so you press the *Open Doors* button, which then allows him to enter the lift. We can thus say that the *Open Doors* operation fed *Lift Entering*.

The next day, you see that annoying guy from the office next to yours approaching the lift. You find shared lift experiences with him awkward and uncomfortable. As you see him approaching the lift, the doors are still open. Cunningly, however, you see the *Close Door* button and press it. The doors close in his face and thus he cannot enter the lift. Therefore, the *Close Doors* operation bled *Lift Entering*. We now have two operations *Open Doors* and *Close Doors*, which interact with *Lift Entering*. The *Lift Entering* operation can be defined as in (2):

(2) *Lift Entering*
outside-lift(X) ⟶ inside-lift(X) / doors = [+open]

This rule can be read as: An individual X can enter the lift (i.e. go from outside the lift to inside the lift) under the condition that the lift's doors are open. With

opaque for counterfeeding and counterbleeding here, because there is no clear-cut one-to-one correspondence between opacity and chronology. More precisely, there are feeding interactions that are opaque (see Baković 2007).

this in mind, we can define the operations *Open Doors* and *Close Doors* as follows:

(3) *Open Doors*
doors[−open] ⟶ doors[+open]

(4) *Close Doors*
doors[+open] ⟶ doors[−open]

What is striking about these two rules is that they have identical formats with the exception that the order of the elements on either side of the arrow is reversed. One rule maps A (doors[−open]) to B (doors[+open]) and the other B to A. This difference results in two distinct types of interaction (feeding vs. bleeding). Therefore, it seems that the alternation between feeding and bleeding can be achieved by simply reversing the order of the input and output of a rule. This is what we will call '(rule) flipping' here. The abstract patterns showing this appear in the literature (e.g. Mascaró 2011), but have either not been noticed or not been explicitly discussed. In particular, there has been no attempt at systematically examining these patterns nor are there any formal accounts of them.

In what follows, we will explore some possibilities of rule internal changes and their effects on the type of interaction between two rules. Section 2 will explore this phenomenon on the basis of concrete linguistic examples from phonology and syntax. These mirror the lift example in the sense that a rule-internal change leads to a different type of interaction. In Section 3, we try to develop a formal account of the conditions on rule interactions (somewhat similar to Baković's (2013) work on string set intersection) that elucidates why certain changes to the structural description of an earlier rule have certain effects on its interaction with a following rule. Finally, some difficulties and further issues are discussed in Section 4. As this is a working paper, there may be an abundance of open issues, so please consider the formal statements as potentially fallible and open to improvement.

2. Linguistic examples

The above lift-riding example – though amusing and thought-provoking – may quite arguably not have any linguistic relevance at all. However, as this section aims to demonstrate, analogous examples can be constructed using data from natural languages, not only in the realm of phonology but also in syntax. The present section will illustrate the effect of rule flipping on three pairs of rules, all standing in a different relation: bleeding, feeding and mutual bleeding (Kiparsky 1971) for both phonology and syntax.

2.1. Phonology

2.1.1. *Feeding:* i-*Epenthesis and Palatalization in Brazilian Portuguese*

The Rio de Janeiro dialect of Brazilian Portuguese has a Palatalization rule (6) that changes the dento-alveolar plosives [t] and [d] into the affricates [tʃ] and [dʒ] before the front high vowel [i]:

(5) *Palatalization in Brazilian Portuguese* (Mateus and d'Andrade 2002)

bato	[bá**t**u]	'I beat'	-	*bate*	[bá**tʃ**i]	's/he beats'
ardo	[áɾ**d**u]	'I burn'	-	*arde*	[áɾ**dʒ**i]	's/he burns'

(6) *Palatalization*[2]

$$\begin{bmatrix} +\text{obstruent} \\ +\text{coronal} \\ +\text{anterior} \end{bmatrix} \longrightarrow \begin{bmatrix} +\text{obstruent} \\ +\text{coronal} \\ -\text{anterior} \end{bmatrix} \Big/ \;\_\_\_\_ \begin{bmatrix} -\text{consonant} \\ +\text{high} \\ -\text{back} \end{bmatrix}$$

Additionally, Brazilian Portuguese has an *i*-Epenthesis rule, which repairs syllables that would otherwise violate the constraints on syllable margins active in the language (such as Sonority Sequencing Generalization, Jespersen 1904, Selkirk 1982; Minimal Sonority Distance, Vennemann 1972, Steriade 1982; Coda Condition, Itô 1988). This is evident in the nativisation of borrowings:

(7) i-*Epenthesis in Brazilian Portuguese* (Mateus and d'Andrade 2002)

pacto	[pák**i**tu]	'pact'
captar	[kap**i**táɾ]	'to capture'
psicologia	[p**i**sikoloʒíɐ]	'psychology'

For the sake of simplicity, let us formulate the rule as one that splits up clusters of obstruents:

[2] Note that the format of this rule diverges from what is common in phonology. Typically, the arrow is only followed by the feature that is manipulated by the rule. For reasons given in Section 3.4 we use a different format.

(8) i-*Epenthesis*

$$\emptyset \longrightarrow \begin{bmatrix} -\text{consonant} \\ +\text{high} \\ -\text{back} \end{bmatrix} / \left[\ +\text{obstruent}\ \right] \underline{\quad\quad} \left[\ +\text{obstruent}\ \right]$$

Rules (6) and (8) stand in a feeding relation. As shown in (9), if the [i] vowel is inserted after a [t] or a [d], the plosives get palatalized.

(9) *Interaction of Palatalization and* i-*Epenthesis in Brazilian Portuguese*

adverso	[a**d**ʒivɛ́χsu]	'adverse'
futebol	[fu**t**ʃibɔ́w]	'football'

If the rule of *i*-Epenthesis were flipped, it would result in the deletion of [i] vowels standing between obstruents:

(10) i-*Deletion (flipped* i-*Epenthesis)*

$$\begin{bmatrix} -\text{consonant} \\ +\text{high} \\ -\text{back} \end{bmatrix} \longrightarrow \emptyset \ / \left[\ +\text{obstruent}\ \right] \underline{\quad\quad} \left[\ +\text{obstruent}\ \right]$$

Thus, if the Spanish word *batido* 'smoothie' ever made its way to Brazilian′ (identical in all respects to Brazilian Portuguese but having rule (10) rather than (8)), it would be pronounced as [bá**t**du], rather than [ba**t**ʃídu]. Thus, the *i*-Deletion rule would bleed the application of Palatalization by removing the context in which the latter rule applies. This is exactly the effect that we have observed with the lift example. Arguably, the flipping of rule (8) leads to a quite unnatural rule. The result of *i*-Deletion is more marked than its input. The rule might be made less unnatural by changing its contextual requirements. For example, one might remodel its left-hand context to the empty set and its right-hand context to [−consonant] to the effect that this amended rule deletes [i] before another vowel. Such deletion is a natural strategy for avoiding hiatus and is common in the languages of the world. But in order for the interaction between *i*-Deletion and Palatalization to remain intact, such changes can only be made within certain limits such that the environments of the two rules do not clash. We will elucidate these limits in Section 3.4.4.

2.1.2. Bleeding: i-*Epenthesis and Voice Assimilation in Lithuanian*

In Lithuanian, homorganic plosive clusters are broken up by the vowel [i]:

(11) i-*Epenthesis in Lithuanian* (Baković 2005)

[at-ko:pʲtʲi]	'to rise'	–	[atʲ**i**-tʲeisʲtʲ]	'to adjudicate'
[ap-kalʲbʲetʲi]	'to slander'	–	[apʲ**i**-putʲi]	'to grow rotten'

In addition, in a cluster of adjacent obstruents, the first one has to agree with the second one in terms of voicing:

(12) *Voice Assimilation in Lithuanian* (Baković 2005)

[a**t**-praʃʲi:tʲi]	'to ask'	–	[a**d**-gautʲi]	'to get back'
[a**p**-ʃaukʲtʲi]	'to proclaim'	–	[a**b**-gautʲi]	'to deceive'

Epenthesis bleeds Voice Assimilation by breaking up clusters of obstruents before they can agree in terms of voicing.

(13) *Interaction of* i-*Epenthesis and Voice Assimilation in Lithuanian* (Baković 2005)

[a**tʲ**i-dʲetʲi]	'to delay'
[a**pʲ**i-bʲekʲtʲi]	'to run around'

Flipping the rule of Epenthesis into the respective rule of Deletion would change the bleeding interaction to feeding. The deletion of a vowel standing between two homorganic obstruents that happen to differ in terms of voicing would give rise to a structure to which Voice Assimilation could (non-vacuously) apply.

2.1.3. *Mutual bleeding: Final Devoicing &* g-*Deletion*

Kiparsky (1982) and Itô and Mester (2003) discuss the following two rules of German:

(14) *Final Devoicing*

$$\begin{bmatrix} \text{+obstr} \\ \text{+voice} \end{bmatrix} \longrightarrow \begin{bmatrix} \text{+obstr} \\ \text{−voice} \end{bmatrix} \Big/ \;\_\_\_\#$$

(15) g-*Deletion*

$$\text{g} \longrightarrow \text{Ø} \,/\, [\text{+nasal}]\_\_$$

These rules are mutually bleeding, with each rule diminishing the set of forms to which the other rule could apply. The ordering of the two rules differs accross dialects. In Standard German, *g*-Deletion applies first. It bleeds Final Devoicing by removing the segment that could undergo it.

(16) *Interaction of* g*-Deletion and Final Devoicing in Standard German*

Underlying Representation	/dɪŋg/
g-Deletion	dɪŋ
Final Devoicing	—
Surface form	[dɪŋ]

In Colloquial Northern German, the order of the two rules is reversed. Here, Devoicing applies first, bleeding *g*-Deletion:

(17) *Interaction of* g*-Deletion and Final Devoicing in Colloquial Northern German*

Underlying Representation	/dɪŋg/
Final Devoicing	dɪŋk
g-Deletion	—
Surface form	[dɪŋk]

Flipping the first rule of either order will feed the rule that applies as second. So, the rule of Final Voicing (flipped Final Devoicing) applied to a word such as *krank* [kʁaŋk] 'ill' would produce a word-final [ng] cluster, to which *g*-Deletion could apply. Conversely, applying *g*-Insertion (flipped *g*-Deletion) to a word ending in [n], such as *Mann* [man] 'man' would produce [mang], which could then undergo Final Devoicing to [mank].

2.2. Syntax

2.2.1. Feeding: Passivization & there*-Insertion*

A case of feeding in syntax is the interaction between passivization and *there*-Insertion (Wasow 1975). If we assume that *there*-Insertion requires the presence of an auxiliary, then this is fed by passivization (which inserts an auxiliary):

(18) The government stationed an agent on the corner.

a. An agent was stationed on the corner. (*Passivization*)

b. There was an agent stationed on the corner. (*there*-Insertion)

We can formulate the rules involved in this interaction as follows:

(19) *Passivization*
$\mathrm{NP_{EXT}}$ V $\mathrm{NP_{INT}}$ → $\mathrm{NP_{INT}}$ AUX V

(20) there-*Insertion*
$\mathrm{NP_{INT}}$ AUX → *there* AUX $\mathrm{NP_{INT}}$

The passivization rule in (19) removes the external argument NP and moves to internal argument NP to the subject position as well as inserting an auxiliary. The *there*-Insertion rule inverts the order of $\mathrm{NP_{INT}}$ and AUX and then inserts *there* clause-initially. We can represent the feeding relation between these rules in (21), (19) feeds (20) as it adds an auxiliary allowing (20) to apply.

(21) *Passivization feeds* there-*Insertion*

	The government stationed an agent on the corner
Passivization	An agent was stationed on the corner
there-*Insertion*	There was an agent stationed on the corner

Assuming that the observations about the effects of flipping rules are correct, then the reverse of passivization should bleed *there*-Insertion. Despite being unintuitive, it is of course a logical possibility that active clauses are derived from underlying passives. If we assume this for the sake of the argument, then the *Depassivization* rule in (22) does in fact bleed *there*-Insertion as it removes the context for it to apply (23).

(22) *Depassivization*
$\mathrm{NP_{INT}}$ AUX V → $\mathrm{NP_{EXT}}$ V $\mathrm{NP_{INT}}$

(23) *Depassivization bleeds* there-*Insertion*

	An agent was stationed on the corner
Depassivization	The government stationed an agent on the corner
there-*Insertion*	—

2.2.2. *Bleeding: Extraposition & Relative Pronoun Deletion*

The next case involves bleeding of Relative Pronoun Deletion by Extraposition (Eckman 1974). In English, it is possible for relative clauses immediately adjacent to the NPs they modify to occur with or without a relative pronoun such as *which* (24). However, this process can only apply if the relative pronoun is adjacent to the modified noun (25):

(24) a. The gun_i [$which_i$ I cleaned] went off.
b. The gun [I cleaned] went off.

(25) a. The gun_i t_j went off [$which_i$ I cleaned]$_j$.
b. *The gun t_j went off [Ø I cleaned]$_j$.

This is captured by the following rule, which states that a relative pronoun can be deleted when it is adjacent to the noun it modifies.

(26) *Relative Pronoun Deletion*
$\text{REL-PRO}_i \rightarrow \text{Ø} / \text{NP}_i$ ___

Furthermore, constituents, including relative clauses, can be extraposed using the following general rule:

(27) *Extraposition*
$[_S \text{ XP }] \rightarrow [_S \text{ }] \text{ XP}$

Since the Relative Pronoun Deletion rule can only apply to relative pronouns adjacent to modified nouns, extraposition of the relative clause will bleed application of Relative Pronoun Deletion.

(28) *Extraposition bleeds Relative Pronoun Deletion*

	The gun_i [$which_i$ I cleaned] went off
Extraposition	The gun_i went off [$which_i$ I cleaned]
Relative Pronoun Deletion	*The gun_i went off [I cleaned]

However, if we were to flip the bleeding rule in this case (Extraposition), we should arrive at a rule that feeds Relative Pronoun Deletion. By reversing the symbols either side of the arrow in the Extraposition rule, we obtain an Intraposition rule that moves sentence-peripheral elements inside the clause:

(29) *Intraposition*
$[_S \text{ }] \text{ XP} \rightarrow [_S \text{ XP }]$

This new rule now, as expected, feeds the rule of Relative Pronoun Deletion:

(30) *Intraposition feeds Relative Pronoun Deletion*

	The gun_i went off [$which_i$ I cleaned]
Intraposition	The gun_i [$which_i$ I cleaned] went off
Relative Pronoun Deletion	The gun_i [I cleaned] went off

2.2.3. *Mutual bleeding: Dative shift & Theme-NP movement*

The interaction of Dative shift and Theme-NP movement in passives represents a case of mutual bleeding in syntax as discussed by den Dikken (1995). There are two main ditransitive structures in English: prepositional datives and double object constructions:

(31) a. John sent a letter to the president.
     b. John sent the president a letter.

It is possible to assume, as den Dikken (1995) does, that the double object construction in (31b) is derived from the prepositional dative construction. Assuming a theory-neutral representation, the Dative shift rule removes the preposition from the indirect object PP and reorders the DO and IO:

(32) *Dative shift*
     $\mathrm{V}\ \mathrm{NP_{DO}}\ [_{\mathrm{PP}}\ \mathrm{P}\ \mathrm{NP_{IO}}] \rightarrow \mathrm{V}\ \mathrm{NP_{IO}}\ \mathrm{NP_{DO}}$

Furthermore, the theme NP argument of a ditransitive verb can be passivized (33). We already encountered the relevant Passivization rule in (19) (repeated in slightly modified form in (34)):

(33) a. John sent a letter to the president.
     b. A letter was sent to the president.

(34) *Passivization*
     $\mathrm{NP_1}\ \mathrm{V}\ \mathrm{NP_2} \rightarrow \mathrm{NP_2}\ \mathrm{AUX}\ \mathrm{V}$

This rule removes the NP in initial position (the subject) and moves the closest NP to subject position. These two rules are mutually bleeding since if one of them applies to a given structure first, the other cannot apply subsequently. For instance, if Dative shift precedes Passivization, Theme-NP movement is impossible due to the fact that the Passivization rule moves the NP furthest to the left.[3]

[3] Note that *The president was sent a letter* is grammatical. What we are trying to capture here are Minimality effects. Since capturing these in rules is not straightforward, and since we are aiming to keep this discussion as theory-neutral as possible, we are referring to a linear notion 'left-most' rather than a hierarchical one such as 'c-command'.

(35) *Dative shift bleeds Theme-NP Movement*

	John sent a letter to the president
Dative shift	John sent the president a letter
Theme-NP Movement	*A letter was sent the president

If the Passivization (Theme-NP Movement) applies first, then Dative shift can no longer apply as no reordering of verb adjacent arguments is possible:

(36) *Theme-NP Movement bleeds Dative Shift*

	John sent a letter to the president
Theme-NP Movement	A letter was sent to the president
Dative shift	*A letter was sent the president

The interesting thing about mutually bleeding rules is that the flipped version of either rule will feed the other rule. For example, the flipped version of Dative shift (37), which we call PPization, will feed rather than bleed Theme-NP movement (38):

(37) *PPization*:
$\mathrm{V\ NP_{IO}\ NP_{DO} \rightarrow V\ NP_{DO}\ [_{PP}\ P\ NP_{IO}]}$

(38) *PPization feeds Theme-NP Movement*

	John sent the president a letter
PPization	John sent a letter to the president
Theme-NP Movement	A letter was sent to the president

Similarly, the flipped version of Passivization (39) now feeds Dative shift:

(39) *Depassivization*
$\mathrm{NP_2\ AUX\ V \rightarrow NP_1\ V\ NP_2}$

(40) *Depassivization feeds Dative Shift*

	A letter was sent to the president
Depassivization	John sent a letter to the president
Dative shift	John sent the president a letter

3. Abstract formulation

In order to understand why the flipping of a rule as demonstrated in the preceding sections actually turns a feeding relation into a bleeding relation, it is useful to give an abstract formulation of the rules involved. Doing this makes it possible to clearly state the formal conditions that need to hold between different parts of the rules for there to be a relationship of one or the other kind. The underlying dependencies between rule flipping and feeding vs. bleeding will then become evident. In addition, further dependencies between counterfeeding and counterbleeding will also become clearer.

But first, let us give a formal representation of rules and the conditions for their interaction.

(41) *Parts and subparts of a rule*

$$\underbrace{\text{L}\quad \overbrace{\text{I}}^{\text{input focus}}\quad \text{R}}_{\text{I–SD}} \quad\longrightarrow\quad \underbrace{\text{L}\quad \overbrace{\text{O}}^{\text{output focus}}\quad \text{R}}_{\text{O–SD}}$$

A rule such as (41) consists of two parts:

- the INPUT STRUCTURAL DESCRIPTION (I-SD), that describes the properties of strings of symbols that the rule can apply to

- the OUTPUT STRUCTURAL DESCRIPTION (O-SD), that describes the string of symbols that is the result of application of the rule

Within these parts one can further distinguish the FOCUS – the part that is actually changed by the rule – from its respective left-hand (L) and right-hand (R) context that remains unchanged by the rule. For expository purposes, we refer to the focus of the I-SD as I(nput focus) and to the focus of the O-SD as O(utput focus). The left-hand and right-hand context will be subsumed under the notion ENV(ironment) which does not refer to both contexts together but rather to each one individually ignoring the distinction between left and right. For now we will simply restrict the focus and the environment to consist of one symbol only. Furthermore, although the linguistic examples above mainly involve interactions on environment, we will only discuss rule INTERACTIONS ON FOCUS here and leave INTERACTIONS ON ENVIRONMENT (McCarthy 1999) for future research. We take the view that before delving into the intricate matter of interactions on environment one first has to have a sound grasp on the simpler cases of interactions on focus.

Bearing this in mind, consider the two rules in (42).

(42) *Abstract rules*
Rule 1: $L^1\, I^1\, R^1 \longrightarrow L^1\, O^1\, R^1$
Rule 2: $L^2\, I^2\, R^2 \longrightarrow L^2\, O^2\, R^2$

In order for these two rules to potentially interact in an excitatory or inhibitory way certain conditions on the symbols L, I, O, and R must hold. These will be laid out in more detail for feeding, bleeding, counterfeeding and counterbleeding in the next sections.

3.1. Feeding

A preceding rule feeds a subsequent rule if the former creates a new string of symbols to which the latter then applies. Since we are only concerned with interactions on focus here, this means that the output focus of Rule 1 needs to be the same as the input focus of Rule 2 and hence:

(43) *Feeding: condition on focus*
$O^1 = I^2$

Additionally, it has to be the case that the environments of the two rules are compatible. That is either the environment of Rule 1 is contained in that of Rule 2 or *vice versa* or both (which is the same as equality). Since they are viewed as single simple symbols a subset relation only holds if one of them is Ø. Formally, this can be stated as in (44)

(44) *Feeding: condition on environment*
$ENV^1 \subseteq ENV^2 \vee ENV^1 \supseteq ENV^2$

If this condition were not fulfilled and for example $L^1 = x$, $R^1 = \emptyset$ and $L^2 = y$, $R^2 = \emptyset$ then the two rules would never interact even if condition (43) held.

An abstract example of feeding is given in (45) where uppercase letters represent foci and lowercase letters represent simple symbols.

(45) *Abstract feeding interaction*
Rule A: $\emptyset\ A\ y \longrightarrow \emptyset\ \boxed{B}\ y$
Rule B: $x\ \boxed{B}\ \emptyset \longrightarrow x\ C\ \emptyset$

Here, the output focus of Rule A is equal to the input focus of Rule B just as stated by condition (43). Additionally, the left-hand context of Rule A is a subset of the left-hand context of Rule B. The right-hand context of Rule B is in turn a subset of that of Rule A. Thus, condition (44) is obeyed.

3.2. Bleeding

A preceding rule bleeds a subsequent rule if the former decreases the number of strings to which the latter could apply. In the case of bleeding on focus, this will happen when the first rule removes of modifies what would have been the input focus of the second rule. That means that the input focus of both rules has to be identical and hence

(46) *Bleeding: condition on focus*
$I^1 = I^2$

Two rules that obey condition (46) can only apply to the same target string, and hence interact, if the condition on environment presented in the previous section is obeyed.

(47) *Bleeding: condition on environment*
$ENV^1 \subseteq ENV^2 \vee ENV^1 \supseteq ENV^2$

Again, even if both rules applied to the same focus but in different environments an interaction would not be possible. (47) ensures that the contexts to the left and to the right of the foci of both rules are compatible with each other. (48) provides an abstract example of bleeding on focus.

(48) *Abstract bleeding interaction*
Rule A: $x \boxed{A} \emptyset \longrightarrow x\ B\ \emptyset$
Rule B: $\emptyset \boxed{A} y \longrightarrow \emptyset\ C\ y$

This time it is the input focus of Rule A which is equal to the input focus of Rule B just as stated by condition (46). The left-hand context of Rule B is a subset of the left-hand context of Rule A. The right-hand context of Rule A is in turn a subset of that of Rule B. Thus, condition (44) is obeyed.

For feeding and bleeding the conditions on environment are the same in (44) and (47). Therefore, if we want to investigate the relationship between both interactions, we need to look at their respective conditions on focus, repeated in (49) for the reader's convenience.

(49) *Flipping*

$$\begin{array}{lccc} \text{feeding: condition on focus} & \boxed{O^1} & = & I^2 \\ & \updownarrow & & \\ \text{bleeding: condition on focus} & \boxed{I^1} & = & I^2 \end{array}$$

The symbol to the right of the equal sign is the same in both conditions. More precisely, for feeding and bleeding, a part of the first rule has to be equal to the input focus of the second rule. The symbols to the left of the equal signs always refer to the first rule. They differ in the following way: For feeding it is the output focus that needs to be identical to the input focus of the second rule whereas for bleeding it is the input focus. It is now clearly visible why a feeding interaction turns into a bleeding interaction when the first of the two rules is flipped. It is precisely because flipping substitutes the input focus for the output focus and *vice versa*.

3.3. Tardy interactions

As is well known, one can turn a timely interaction such as feeding andor bleeding into a tardy interaction (traditionally called 'opaque') such as counterfeeding or counterbleeding by reversing the order of application of two rules. Since the order of application is represented by the superscripts in (49), it should be the case that by swapping these superscripts one arrives at the conditions for counterfeeding and counterbleeding respectively. For counterfeeding, this would result in (50)

(50) *Counterfeeding: condition on focus*
$O^2 = I^1$

Counterfeeding is usually said to hold between two rules if one of them creates the target for the other but cannot feed it because it applies too late. This is exactly what (50) describes. Again, the condition on the environment is the same as for feeding and bleeding. An abstract example of counterfeeding is (51).

(51) *Abstract counterfeeding interaction*

$$\begin{array}{lcccl} \text{Rule A:} & x\,\boxed{B}\,\emptyset & \longrightarrow & x\ C\ \emptyset \\ \text{Rule B:} & \emptyset\ A\ y & \longrightarrow & \emptyset\,\boxed{B}\,y \end{array}$$

The situation is a bit different for a counterbleeding interaction. By swapping the superscripts in (46) one obtains

(52) *Counterbleeding: condition on focus*
$I^2 = I^1$

Counterbleeding is said to hold between two rules if one of them would destroy the target of the other but does not bleed it because it applies too late. Since the condition on bleeding (46) is equal to that on counterbleeding (52) it follows that for interactions on focus every bleeding interaction is also a counterbleeding interaction; more precisely: bleeding on focus between two rules is necessarily mutual bleeding. The condition on the environment is the same as that for bleeding, feeding and counterbleeding. A change in the order of application therefore has no effect on the kind of interaction (compare the abstract counterfeeding interaction in (53) with the abstract bleeding interaction in (48)).

(53) *Abstract counterbleeding (mutual bleeding) interaction*
Rule A: $\emptyset\ \boxed{\text{A}}\ \text{y} \longrightarrow \emptyset\ \text{C}\ \text{y}$
Rule B: $\text{x}\ \boxed{\text{A}}\ \emptyset \longrightarrow \text{x}\ \text{B}\ \emptyset$

3.4. Sets of feature-value pairs

Up to now we have stated the different conditions for feeding and bleeding using simple symbols that do not have any internal structure. But as we can see from the phonological examples in Section 2, rules manipulate features rather than whole segments. In this section we will therefore reformulate the conditions on focus and environment such that they become statements on sets of feature-value pairs.

In order to arrive at a comprehensible formulation from which the relations between types of interaction are immediately obvious (as was the case with the statements on simple symbols), we make the following assumptions:

1. Feature-value pairs are regarded as primitives. There is no relation whatsoever between $+F_1$ and $-F_1$. They are different elements and it is impossible to state that they both include the same feature F_1.

2. Rules do not apply vacuously. Commonly, phonological rules are often given as [+obstr]# → [−voice]#, where the rule would vacuously apply

to voiceless obstruents. We formulate them in such a way that both input and output focus are identical except for the features manipulated by the rule, i.e. [+obstr,+voice] → [+obstr,−voice].

Without these assumptions a more complicated formulation of the conditions would be required. For feeding this would probably have to be $\exists F(F \in \mathrm{I}^1 \wedge F \in \mathrm{O}^1 \wedge F \in \mathrm{I}^2 \wedge v(F, \mathrm{I}^1) \neq v(F, \mathrm{O}^1) = v(F, \mathrm{I}^2))$ where F is a feature and $v(F, \mathrm{X})$ is its value in set X. Formulated like this, the relations between interactions become more difficult to grasp. Also, we do not yet fully understand their implications. For these reasons we will adhere to the assumptions above.

3.4.1. *Feeding*

Let us imagine a universe where segments are composed of four binary features F_1, F_2, F_3 and F_4. The rules in (42) might then be reformulated in featural terms as in (54), where we additionally formulate three more versions of Rule 2 in order to exemplify the various possibilities of interaction. For better readability we only give the focus in feature notation. The left-hand and right-hand context are understood to be a set of feature-value pairs as well. For the sake of concreteness, we assume L^1 and L^2 to be $\{+\mathrm{F}_1, +\mathrm{F}_2, -\mathrm{F}_3\}$ and R^1 and R^2 to be $\{-\mathrm{F}_1, -\mathrm{F}_2\}$ for the time being such that the condition on environment is fulfilled.

(54) *Abstract rules operating on sets of feature-value pairs (feeding)*

$$\text{Rule 1:}\quad \mathrm{L}^1 \begin{bmatrix} +\mathrm{F}_1 \\ +\mathrm{F}_2 \\ +\mathrm{F}_3 \\ \phantom{+\mathrm{F}_4} \end{bmatrix} \mathrm{R}^1 \longrightarrow \mathrm{L}^1 \begin{bmatrix} -\mathrm{F}_1 \\ +\mathrm{F}_2 \\ +\mathrm{F}_3 \\ \phantom{+\mathrm{F}_4} \end{bmatrix} \mathrm{R}^1$$

$$\text{Rule 2:}\quad \mathrm{L}^2 \begin{bmatrix} -\mathrm{F}_1 \\ +\mathrm{F}_2 \\ +\mathrm{F}_3 \\ +\mathrm{F}_4 \end{bmatrix} \mathrm{R}^2 \longrightarrow \mathrm{L}^2 \begin{bmatrix} -\mathrm{F}_1 \\ -\mathrm{F}_2 \\ +\mathrm{F}_3 \\ +\mathrm{F}_4 \end{bmatrix} \mathrm{R}^2 \qquad \mathrm{O}^1 \subseteq \mathrm{I}^2$$

$$\text{Rule 2}':\quad \mathrm{L}^2 \begin{bmatrix} -\mathrm{F}_1 \\ +\mathrm{F}_2 \\ \phantom{+\mathrm{F}_3} \\ \phantom{+\mathrm{F}_4} \end{bmatrix} \mathrm{R}^2 \longrightarrow \mathrm{L}^2 \begin{bmatrix} -\mathrm{F}_1 \\ -\mathrm{F}_2 \\ \phantom{+\mathrm{F}_3} \\ \phantom{+\mathrm{F}_4} \end{bmatrix} \mathrm{R}^2 \qquad \mathrm{O}^1 \supseteq \mathrm{I}^2$$

$$\text{Rule } 2'':\ L^2\begin{bmatrix} -F_1 \\ \\ +F_4 \end{bmatrix}R^2 \longrightarrow L^2\begin{bmatrix} -F_1 \\ \\ -F_4 \end{bmatrix}R^2 \qquad O^1 \cap I^2 \neq \emptyset$$

$$\text{Rule } 2''':\ L^2\begin{bmatrix} +F_2 \\ +F_3 \\ +F_4 \end{bmatrix}R^2 \longrightarrow L^2\begin{bmatrix} -F_2 \\ +F_3 \\ +F_4 \end{bmatrix}R^2 \qquad O^1 \cap I^2 \neq \emptyset$$

In (54), Rule 1 feeds Rules 2, 2′ and 2″, where the input focus of Rule 2 is a superset and that of Rule 2′ a subset of the output focus of Rule 1. The input foci of Rule 2″ and Rule 2‴ both have a non-empty intersection with the output focus of Rule 1. The interaction between Rule 1 and 2″ is a classical feeding relation: Rule 1, by changing $+F_1$ to $-F_1$, creates the input for Rule 2″, which otherwise could not apply to the given target. The interaction between Rule 1 and 2‴ however is not feeding: Although Rule 2‴ could apply to the output of Rule 1 (given a respective target $\{+F_1, +F_2, +F_3, +F_4\}$) it could also apply to the target itself. There exists no target such that Rule 2‴ can only apply after Rule 1 has changed the target accordingly.

The question then is, what are the conditions that have to hold between sets of feature-value pairs in order to establish a feeding interaction? Or in other words, what distinguishes Rule 2‴ from the other Rules 2, 2′ and 2″?

The crucial difference is that the intersection of I^2 and O^1 for the latter Rules contains the feature whose value has been changed by Rule 1 whereas the intersection of I^2 and O^1 for Rule 2‴ does not. Regarding feature-value pairs as primitives, this is set-theoretically expressible as:

(55) *Feeding: condition on focus for feature-value sets*
$(O^1 \cap I^2) \nsubseteq I^1$

3.4.2. *Bleeding*

In order for a bleeding relation to hold between two rules one of them has to be able to apply to a subset of the targets that the other one applies to. In addition, the rule that applies first needs to alter the target in such a way that it does not fit the I-SD of the subsequent rule any more. The first requirement is fulfilled if $I^1 \cap I^2 \neq \emptyset$, the second one if this intersection is no subset of the output focus of the first rule, i.e. the feature that is changed by the first rule has to be an element of the intersection. Since the empty set is a subset of every set by definition, the second requirement entails the first one, which hence does not need to be explicitly stated.

(56) *Bleeding: condition on focus for feature-value sets*
$(I^1 \cap I^2) \nsubseteq O^1$

Here again, as with the simpler formulations above, a flipping of the first rule substitutes its input focus for its output focus and *vice versa*. This mirrors the different positions of these elements within the set-theoretic conditions for feeding (55) and bleeding (56).

(57) *Link between feeding and bleeding*

feeding: $\boxed{O^1} \cap I^2 \nsubseteq \boxed{I^1}$

bleeding: $\boxed{I^1} \cap I^2 \nsubseteq \boxed{O^1}$

Thus, in (58) (which is the same as (54) but with Rule 1 flipped) Rule 1 bleeds Rules 2, 2′ and 2″ but does not bleed Rule 2‴. The intersection of the input focus of Rule 1 with each of the input foci of Rules 2, 2′ and 2″ is not a subset of the output focus of Rule 1. This is exactly what condition (56) requires for a bleeding interaction. The relevant intersection of Rule 1 with Rule 2‴ however is a subset of the output focus of Rule 1. Conforming to (56) there is no bleeding interaction between these two rules in (58).

(58) *Abstract rules operating on sets of feature-value pairs (bleeding)*

$$\text{Rule 1:}\quad L^1 \begin{bmatrix} -F_1 \\ +F_2 \\ +F_3 \end{bmatrix} R^1 \longrightarrow L^1 \begin{bmatrix} +F_1 \\ +F_2 \\ +F_3 \end{bmatrix} R^1$$

$$\text{Rule 2:}\quad L^2 \begin{bmatrix} -F_1 \\ +F_2 \\ +F_3 \\ +F_4 \end{bmatrix} R^2 \longrightarrow L^2 \begin{bmatrix} -F_1 \\ -F_2 \\ +F_3 \\ +F_4 \end{bmatrix} R^2 \qquad (I^1 \cap I^2) \nsubseteq O^1$$

$$\text{Rule } 2'\text{:}\quad L^2\begin{bmatrix} -F_1 \\ +F_2 \\ \\ \\ \end{bmatrix}R^2 \longrightarrow L^2\begin{bmatrix} -F_1 \\ -F_2 \\ \\ \\ \end{bmatrix}R^2 \qquad (I^1 \cap I^2) \nsubseteq O^1$$

$$\text{Rule } 2''\text{:}\quad L^2\begin{bmatrix} -F_1 \\ \\ \\ +F_4 \end{bmatrix}R^2 \longrightarrow L^2\begin{bmatrix} -F_1 \\ \\ \\ -F_4 \end{bmatrix}R^2 \qquad (I^1 \cap I^2) \nsubseteq O^1$$

$$\text{Rule } 2'''\text{:}\quad L^2\begin{bmatrix} \\ +F_2 \\ +F_3 \\ +F_4 \end{bmatrix}R^2 \longrightarrow L^2\begin{bmatrix} \\ -F_2 \\ +F_3 \\ +F_4 \end{bmatrix}R^2 \qquad (I^1 \cap I^2) \subseteq O^1$$

3.4.3. *Tardy interactions*

As was the case with the formalisations for simple symbols in the preceding sections a swapping of superscripts, i.e. reversal of the order of application, should give us the conditions for counterfeeding and counterbleeding. The formulation for counterfeeding is

(59) *Counterfeeding: condition on focus for feature-value sets*
$(O^2 \cap I^1) \nsubseteq I^2$

As can be checked by reversing the order of application in (54), this condition holds for all the rules (2, 2′ and 2″) that counter-feed Rule 1. It also correctly excludes Rule 2‴ from the counterfeeding relation.

For counterbleeding the condition is

(60) *Counterbleeding: condition on focus for feature-value sets*
$(I^2 \cap I^1) \nsubseteq O^2$

Unlike before, the two conditions (60) (counterbleeding) and (56) (bleeding) are not equal to each other. In the former the intersection of I^2 and I^1 must not be a subset of O^2 while in the latter it must not be a subset of O^1. This means that a rule can actually bleed another rule but not counter-bleed it at the same time and *vice versa*. A simple example illustrates this.

(61) *Bleeding ≠ counterbleeding for feature-value sets*

$$\text{Rule 1: } L^1 \begin{bmatrix} +F_2 \\ +F_3 \\ +F_4 \end{bmatrix} R^1 \longrightarrow L^1 \begin{bmatrix} -F_2 \\ +F_3 \\ +F_4 \end{bmatrix} R^1 \qquad (I^1 \cap I^2) \begin{array}{l} \nsubseteq O^1 \\ \subseteq O^2 \end{array}$$

$$\text{Rule 1}': L^1 \begin{bmatrix} -F_1 \\ \\ \\ +F_4 \end{bmatrix} R^1 \longrightarrow L^1 \begin{bmatrix} -F_1 \\ \\ \\ -F_4 \end{bmatrix} R^1 \qquad (I^1 \cap I^2) \begin{array}{l} \subseteq O^1 \\ \nsubseteq O^2 \end{array}$$

$$\text{Rule 2: } L^2 \begin{bmatrix} -F_1 \\ +F_2 \\ +F_3 \\ \\ \end{bmatrix} R^2 \longrightarrow L^2 \begin{bmatrix} +F_1 \\ +F_2 \\ +F_3 \\ \\ \end{bmatrix} R^2$$

In (61), the intersection of the input foci of Rule 1 and 2 ($\{+F_2, +F_3\}$) is not a subset of the output focus of Rule 1 but of that of Rule 2. Hence, Rule 1 bleeds Rule 2 (by condition (56)) but does not counter-bleed it (by condition (60)). On the other hand, the intersection of the input foci of Rule 1′ and 2 ($\{-F_1\}$) is a subset of the output focus of Rule 1′ but not of that of Rule 2. Hence, Rule 1′ does not bleed Rule 2 (by condition (56)) but counter-bleeds it (by condition (60)).

3.4.4. *Conditions on environment*

In the previous sections the context of the flipped rule was kept constant. However, as noted in Section 2.1.1, swapping the input and the output of a phonological rule will most likely make the resulting rule unnatural. This is because phonological rules usually apply in order to repair marked structures. Reversing the process makes the output structure more marked. However, it is possible to change the context of the flipped rule to make it more plausible. There are various possibilities to do that, but not all of them preserve the interaction between the flipped rule and the subsequent rule.

Consider the following environments of two rules that show interaction on focus. ENV^{1-5} are variations of the environment of a preceding rule and ENV^6 is the unaltered environment of a subsequent rule 6.

(62) *Relations between environments*

$$\frac{\begin{array}{ccccc} \text{ENV}^1 & \text{ENV}^2 & \text{ENV}^3 & \text{ENV}^4 & \text{ENV}^5 \\ \begin{bmatrix} +F_1 \\ \\ \\ \end{bmatrix} & \begin{bmatrix} +F_1 \\ +F_2 \\ +F_3 \\ \end{bmatrix} & \begin{bmatrix} \\ \\ \\ +F_4 \end{bmatrix} & \begin{bmatrix} +F_1 \\ \\ -F_3 \\ \end{bmatrix} & \begin{bmatrix} +F_1 \\ -F_2 \\ \\ \end{bmatrix} \end{array}}{\begin{array}{c} \text{ENV}^6 \\ \begin{bmatrix} +F_1 \\ +F_2 \\ \\ \end{bmatrix} \end{array}}$$

Environment 1 is a subset, environment 2 a superset of environment 6. For these two environments the interaction on focus between the respective two rules remains intact. They obey the condition on environment for simple symbols repeated in (63).

(63) *Condition on environment (for simple symbols)*
$\text{ENV}^1 \subseteq \text{ENV}^2 \vee \text{ENV}^1 \supseteq \text{ENV}^2$

However, if one changes the environment of the preceding rule to ENV^3 with the effect that condition (63) is not obeyed anymore, the interaction still pertains. Since the intersection of ENV^3 and ENV^6 is empty one might amend condition (63) to alternatively require an empty intersection of environments in cases where none of the environments is a subset of the other. But this is still not sufficient as is shown by environments 4 and 5. Both of them are neither a subset nor a superset of ENV^6 and their respective intersections with ENV^6 are not empty. Nevertheless, if the environment of the preceding rule were changed to ENV^4 the interaction between this preceding rule and the subsequent rule would remain intact whereas if the environment were altered to ENV^5 the interaction would be lost. The relevant difference between ENV^4 and ENV^5 is that the latter contains a feature that is also present in ENV^6 but has a contradicting value, i.e. $-F_2$ in ENV^5 vs. $+F_2$ in ENV^6. As it stands, there is no way to formulate this while retaining assumption 1 made in Section 3.4 that feature-value pairs are primitives. By allowing feature-value pairs to be split up into a feature *F* and a value *v* one were able to formulate the condition on environment as (64).

(64) *Condition on environment (without assumption 1)*
$\forall F((F \in \mathrm{ENV}^1 \wedge F \in \mathrm{ENV}^2 \Rightarrow \nu(F, \mathrm{ENV}^1) = \nu(F, \mathrm{ENV}^2))$

Here, ENV^1 is the environment of the preceding rule while ENV^2 is that of the subsequent rule. Condition (64) states that if there is an instance of the feature F in the environment of rule 1 and in that of rule 2 both instances have to bear the same value in order for an interaction between the two rules to hold.

From the above we can conclude that assumption 1 makes the formal description of rule interaction devised in the preceding sections too restrictive. Although it has been useful in the sense that it kept the system simple and easily comprehensible it will eventually have to be abandoned in favour of a more complicated system that is able to refer to features and their values separately and thus to correctly describe the dependencies between two interacting rules.

4. Applications to syntax

The conditions on interactions in phonology and in terms of abstract features may, intuitively, not seem compatible with syntax. However, if these interactions such as feeding and bleeding actually exist in syntax, then there should be no reason why these conditions should not hold there too. In this section, we will discuss interactions and flipping in syntax in more detail and explore the extent to which the set-theoretic formulation of the conditions on interactions developed in the previous sections can be applied to syntax. We will see that one of the main problems that arises is that the objects that phonological rules apply to are features organized into sets, which are by definition unordered. On the other hand, the objects manipulated by syntax are linearly ordered. Thus, it is necessary to view the set-theoretic conditions on simple symbols as conditions on sets of ordered elements (denoting linear precedence relations). The final section will discuss some implications of the notion of flipping for cases of analytical ambiguity.

4.1. Set-theoretic approaches to syntax

In order to see the problem syntactic rules pose for set-theoretic definitions of feeding and bleeding, consider the interaction between VP Topicalization and *do*-support. In English, VP Topicalization is only grammatical with *do*-support:

(65) John wrote a book.

a. [$_{VP}$ write a book] John did t_{VP}.

b. *[$_{VP}$ write a book] John t_{VP}.

Thus, we can say that VP Topicalization feeds *do*-support. We can describe the rules involved in this interaction as follows (where # stands for a sentence boundary):

(66) *VP Topicalization*
NP VP → VP NP / ___#

(67) do-*support*
Ø → do / NP_{SUB} ___#

(66) moves a sentence-final VP to the front of the clause and (67) inserts *do* before a sentence-final (subject) NP. In order to check whether the condition on feeding holds, we will represent the rules using the following notation:

(68) *Feeding order*

VP Topicalization:	NP VP #	→	VP NP #
do-*support*:	VP NP #	→	VP NP do #

Recall, that the basic condition that holds between two rules in a feeding relation is $O^1 = I^2$. This is indeed the case for these two rules since both O^1 and I^2 are *VP NP* indicated by the $\boxed{\text{box}}$ below:

(69) *Feeding order*

VP Topicalization:	NP VP_{I^1} #	→	$\boxed{\text{VP NP}}_{O^1}$ #
do-*support*:	$\boxed{\text{VP NP}}_{I^2}$ #	→	VP NP do #

Furthermore, recall that feeding was also defined in set-theoretic terms for sets of feature-value pairs. The exact condition on feeding was the following:

(70) *Feeding: condition on focus*
$(O^1 \cap I^2) \nsubseteq I^1$

If we compare this to the example in (69), we see that it does not seem to hold if we simply look at the symbols. The set intersection of O^1 and I^2 (marked with a $\boxed{\text{box}}$) is {VP, NP}. According to the condition in (70), this should not constitute a subset of I^1 (marked with a dashed box). However, I^1 corresponds to the set {NP, VP}. Since sets are unordered by nature, these sets – or the symbols contained in them – stand in a subset relation. Does this mean that the set-theoretic conditions cannot be applied to syntax? Perhaps not. The problem here seems to be that syntax manipulates linear order.[4] Thus, in the present example, the fact that the VP appears in a different position in the string creates the necessary environment for *do*-support to apply. If we simply treat syntactic strings as simple sets of the symbols contained in them, then it seems we miss this insight.

Instead, we can view syntax as sets of ordered pairs. If we want to capture the fact that NP precedes VP in an example such as (68), we can view the set corresponding to this string not as {NP, VP} but in fact as {<NP, VP>}, where this notation stands for a linearization statement that NP precedes VP. As a result, we can translate (68) into sets of ordered pairs as follows (cf. Adger 2013):

(71) *Feeding order*:
VP Topicalization: {<NP, VP>} $_{I^1}$ → {<VP, NP>} $_{O^1}$
do-*support*: {<VP, NP>} $_{I^2}$ → {<VP, NP>,<VP, do>, <NP, do>}

Now, it becomes clear that conditions on feeding in fact do hold. Furthermore, under this view we can see that the conditions on other interaction types also hold. If we reverse the order of application, then the condition on counterfeeding in (72) should also hold. (73) shows that this is the case.

(72) *Counterfeeding: condition on focus*
$(O^2 \cap I^1) \nsubseteq I^2$

(73) *Counterfeeding order*:
do-*support*: {<VP, NP>} $_{I^1}$ → {<VP, NP>,<VP, do>, <NP, do>}
VP Topicalization: {<NP, VP>} $_{I^2}$ → {<VP, NP>} $_{O^2}$

Furthermore, we can now test whether the flipped version of VP Topicalization confirms to the conditions on bleeding. The flipped version of VP Topicalization

[4] The same problem would arise if we tried to account for metathesis in a similar way. The approach developed in the present section could potentially provide a solution, however, a unified treatment of all types of phonological operations requires further research.

would be a rule that moves a sentence-initial VP to final position and is given in (74):

(74) *VP Lowering*
VP NP → NP VP / ___#

If we have this rule precede the unchanged *do*-support, it becomes clear that the condition on bleeding ($I^1 \cap I^2 \notin O^1$) also holds.

(75) *Bleeding order (flipped rule)*

VP Lowering: $\boxed{\{\langle \text{VP, NP} \rangle\}}_{I^1} \rightarrow \boxed{\{\langle \text{NP, VP} \rangle\}}_{O^1}$

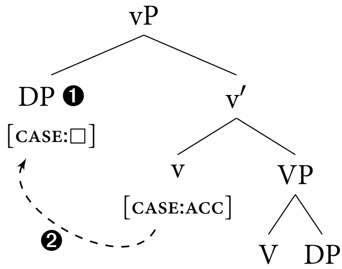
do-*support*: $\boxed{\{\langle \text{VP, NP} \rangle\}}_{I^2} \rightarrow \{\langle \text{VP, NP} \rangle, \langle \text{VP, do} \rangle, \langle \text{NP, do} \rangle\}$

If we were not dealing with sets of ordered pairs, we would have the same problem as before, namely that the subset relation would in fact hold between the foci of the respective rules since we would have unordered sets of symbols. This example should serve to illustrate an important difference between the nature of interactions in phonology, which operates on sets of unordered features/feature-value pairs, and syntax, which operates on linear strings. If we take this consideration into account, it becomes clear that the conditions that hold for phonology and for abstract examples are also upheld in syntax.

4.2. Analytical ambiguity

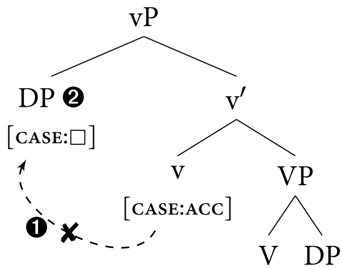
One implication of the discovery of feeding/bleeding alternations by means of flipping is that it opens up new analytical possibilities in syntax. A number of syntactic phenomena can be analyzed as tardy interactions, whereby one rule applies too late to have an effect. An example of this is counterfeeding of Spec-Head Agree. If a head v can carry out Agree for assignment of, say, accusative case with either its complement or its specifier (with a preference for Spec-Head Agree; cf. *Spec-Head bias*), then External Merge – an operation, which introduces a specifier of v – will feed Spec-Head Agree if it applies first (76).

(76) *Feeding of Spec-Head Agree*



This is the analysis that is proposed for argument encoding in Müller (2009). Following Murasugi (1992), he assumes that v assigns an 'internal case' corresponding to accusative or ergative. Whereas ergative is marked on the external argument in ergative-absolutive languages, external arguments are not marked with accusative in nominative-accusative languages. This is puzzling since we know that the external argument is in a Spec-Head configuration at some point in the derivation – this begs the question as to why it is not assigned accusative case in this position. The solution proposed by Müller (2009) is that Merge comes too late to feed Spec-Agree (i.e. it counterfeeds it):

(77) *Counterfeeding of Spec-Head Agree*



This becomes relevant for the discussion of flipping in the following way: If Merge feeds Spec-Head Agree, then the flipped version of Merge should bleed Spec-Head Agree. The question arises as to what the flipped version of Merge would look like. If we conceive of Merge as an operation that moves a syntactic object from the workspace (where it is assembled) into the tree, we can represent the movement involved as follows:

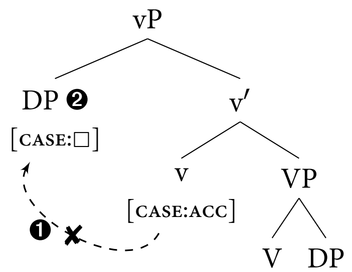
(78) *External Merge*
XP(workspace) ⟶ XP(tree)

We know that – in the most basic sense – flipping a rule involves reversing its input and output. Applying this change to (78) yields the following:

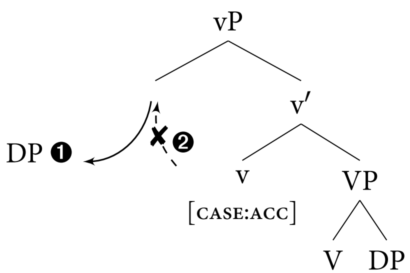
(79) *Reversed Merge (*Sideward Movement*)*
XP(tree) ⟶ XP(workspace)

The operation in (79) moves syntactic objects from the tree into the workspace. Interestingly, this kind of operation actually exists and is commonly referred to as *Sideward Movement* (Nunes 2004). This means that we now actually have two operations that can explain the fact that Spec-Head Agree does not apply in nom-acc languages such as English: (i) Merge applies after Agree (counterfeeding) (80), (ii) the context for Spec-Head Agree to apply is destroyed by timely application of Sideward Movement (bleeding) (81):

(80) *Counterfeeding of Spec-Head Agree*



(81) *Bleeding of Spec-Head Agree*



Both of these are viable options in order analyze the non-application of a particular process. If we assume that movement (Internal Merge) can actually be decomposed into Sideward Movement & External Merge, then there is really no obvious reason to favour one analysis over the other. Thus, we have a case of genuine analytical ambiguity. There may be other reasons to favour one analysis over the other, but both exist as logical possibilities. The implication for analyses proposing 'opaque' interactions such as counterfeeding of counterbleeding is that there will – at least in theory – always be a 'transparent' alternative to an 'opaque' analysis. In this case, it is possible to reanalyze counterfeeding of Spec-Head Agree as bleeding of Spec-Head Agree by the flipped version of the original feeding rule. Thus, we arrive at a systematic way of generating alternative syntactic analyses. If we start from a tardy interaction (counterfeeding/counterbleeding), reverse the order of application and then apply flipping to the first rule, we will generate the corresponding timely interaction (bleeding/feeding). Although this may not always offer a plausible alternative, it means that there is always a transparent, or *timely*, alternative to every opaque interaction that should at least be considered. Uncovering the nature of flipped rules and feeding/bleeding alternations provides a systematic way of arriving at these alternatives.

5. Summary

In this paper, we explored the effect of 'flipping' rules. In the typology of grammatical interactions, the relationship between feeding and counterfeeding on the one hand, and bleeding and counterbleeding on the other is well understood. We know that if we want to turn feeding into counterfeeding, for example, we only need to reverse the order of application. What is less clear is what kind of relationship, if any, holds between feeding and bleeding, and counterfeeding and counterbleeding. We have shown that there is an active alternation between the two kinds of interaction that can be achieved in practice by inverting (or 'flipping') the input and output of the feeding or bleeding rule. It was shown that this is a transformation that can be readily applied to examples from both phonology and syntax. In order to better understand why feeding and bleeding stand in this relation, we sought a formal definition of the exact conditions on feeding and bleeding. We found that there exist certain conditions on each interaction type which can be partially stated in set-theoretic terms and that flipping is in fact just exchanging symbols in these set-theoretic statements in a systematic way. The main focus of the paper was placed on intertactions on focus. The conditions on interactions on environment seem much more complex and require further research. Furthermore, it was shown that the formulation of the various conditions on symbols and feature-value pairs can in fact be extended to syntax if we view syntax as operating on sets of ordered pairs corresponding to linearization statements. One of the main achievements of this article is that it provides a systematic way to turn feeding into bleeding and *vice versa*. Furthermore, we have reached a better understanding of the exact conditions that hold on the four familiar interaction types.

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