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Chapter 1

Introduction

It is generally accepted that language variability is not limitless and that there are restrictions on the attested patterns. Out of this view grew the notion of universals in linguistics (Greenberg, 1963). Chomsky (1965) classifies linguistic universals as formal and substantive.

> It is useful to classify linguistic universals as *formal* and *substantive*. A theory of substantive universals claims that items of a particular kind in any language must be drawn from a fixed class of items. For example, Jakobson's theory of distinctive features can be interpreted as making an assertion about substantive universals... [where] each [element] has a substantive acoustic-articulatory characterization independent of any particular language. ... It is also possible, however, to search for universal properties of a more abstract sort. Consider a claim that the grammar of every language meets certain specified formal conditions. ... The property of having a grammar meeting a certain abstract condition might be called a *formal* linguistic universal, if shown to be a general property of natural languages. (Chomsky, 1965, 28)

Linguistic research grounded in mathematics and computation is rooted in the search for formal universals. For example, recent work on subregular complexity (Aksënova et al. 2016; Graf 2019b, 2018; Heinz 2018 and references therein) shows that many aspects of language — from phonology to morphology, syntax, and even semantics — are very limited in terms of their computational complexity. These limits can be invoked to explain why certain plausible patterns do not seem to occur across languages. For example, this perspective can explain that why there cannot be a process of intervocalic voicing only between vowels in odd and even positions, but not between even and odd ones. However, it cannot explain why linguists have found no process of intervocalic devoicing even though it would have the same subregular complexity as intervocalic voicing. Here it is the substance of the involved elements that matters, rather than the complexity of the process. The central claim of this dissertation is that the mathematical notion of monotonicity can close this gap as it provides a fruitful, formally rigorous perspective on linguistic substance.

In simple terms, Monotonicity is closely related to the linguistic notion of order preservation. In mathematics, a monotonic function f that relates elements x and y of some ordered structure A to elements of another ordered structure B must be such that the order of $f(x)$ and $f(y)$ in B does not directly contradict that of x and y in A. The function $f(x) = 2x$ from integers to integers, for instance, is monotocially increasing because whenever $x \leq y$, it also holds that $f(x) = 2x \leq 2y = f(y)$. The function $f(x) = \frac{x}{2}$, on the other hand, is monotonicially decreasing — it still preserves the relative order of elements, although in reverse. When we draw these functions in a coordinate system, their monotonicity is reflected by the fact that their corresponding line never changes direction: $f(x) = 2x$ moves upward and never slopes downward, whereas $f(x) = \frac{x}{2}$ always moves downward and never slopes upward. Contrast this against the function $f(x) = x^2$, which moves downward for negative integers ($f(-5) = 25 \geq f(-3) = 9$) but upward for positive integers ($f(3) = 9 \leq f(5) = 25$). The function $f(x) = x^2$ thus is non-monotonic. While these examples stay within the familiar realm of numbers, monotonicity is a much more general notion and can be fruitfully applied to all kinds of functions between ordered structures, including linguistic ones, as I will demonstrate in this thesis.

The central goal of this dissertation is to show how this mathematical notion can be applied to linguistic data. In doing so, I use Graf's account, which proposes monotonicity as a formal universal of morphosyntax (Graf, 2019a). This approach is based on two criteria: I) each morphosyntactic domain comes with a base hierarchy (e.g. person: $1 < 2 < 3$), and II) the mappings from a hierarchy to surface forms must be (feasibly) monotonic (I explain the notions 'monotonicity' and 'feasible monotonicity' in more detail in the next chapter, section 2.2). This dual specification puts this approach at a major advantage because it combines substantive universals (linguistic hierarchies) and formal universals (monotonicity) to give a tighter characterization of natural language.

Adjectival paradigms, for instance, come with a linguistically motivated hierarchy where the comparative form is always located between the positive and the superlative. The three surface forms associated with this underlying order show different suppletive patterns across languages: '***big**-**big**ger-**big**gest*' (AAA), '*bad, **wors**e, **wors**t*' (ABB), or '*bonus, melior, optimus*' (ABC), but never '***bon**us, melior, **bon**imus*', hence *ABA (Bobaljik, 2012). The suppletion patterns (shown in a bold font) only show mappings that are monotonic, and a monotonic function never maps the ordering of positive-comparative-superlative to ABA. This is why Graf (2019a) introduces the *ABA generalization as an instance of monotonicity. Section §2.2.1 of the next chapter provides a more comprehensive account of this discussion.

Within linguistics, monotonicity has been largely limited to semantics. Establishing the direction of entailment in propositional operators is one example where monotonicity proves helpful. For instance, π is an upward-entailing operator iff for any two sentences p and q such that $p \rightarrow q$: $\pi(p) \rightarrow \pi(q)$. (*Paniz is a semanticist.* $\rightarrow$ *Paniz is a linguist.*) Monotonicity can help us explain much more in language, however, and there are studies showing how it is linked to many fundamental aspects of linguistic processing, reasoning, and grammar (Icard and Moss, 2014). In this dissertation, I use monotonicity to provide a formal basis for certain morphosyntactic patterns. I present typological data mapping the attested variation in three morphosyntactic domains: tense syncretism, resolved gender agreement, and person-number syncretism. I then show that all the attested patterns follow monotonic mappings.

Graf's (2019a) approach uses monotonicity associated with order theory to account for paradigmatic gaps. However, there are other senses in which monotonicity —or its inverse notion— has been used in the literature. In order to sharpen the reader's understanding of this approach by way of contrasting it with others, I briefly discuss a linguistic formalism which, following the Computer Science literature on modeling inheritance within structures, argues for a nonmonotonic inheritance system. Even though the context in which monotonicity is defined within that formalism is not related to the way it is used by Graf (2019a), I include a short discussion of it to help the interested reader appreciate the ways in which these accounts are similar, but different.

Some linguists, specifically those working on formal approaches to morphological organization, have argued in favor of a nonmonotonic structure in order to account for morphological regularities, subregularities, and exceptions. One famous such stand comes from Network Morphology (Corbett and Fraser, 1993) whose treatment of default inheritance and exceptional case default is similar to the nonomonotonic structure of DATR (Evans and Gazdar, 1989a,b). The nonmonotonic inheritance networks were originally developed for general knowledge representation purposes in Artificial Intelligence, and DATR develops that idea into a system of equations for lexical knowledge representation (Evans and Gazdar, 1996, 166).

> Irregular lexemes are standardly regular in some respect. Most are just like regular lexemes except that they deviate in one or two characteristics. What is needed is a natural way of saying "this lexeme is regular except for this property." One obvious approach is to use nonmonotonicity and inheritance machinery to capture such lexical irregularity (and subregularity), and much recent research into the design of representation languages for natural language lexicons has thus made use of nonmonotonic inheritance networks (or "semantic nets") as originally developed for more general representation purposes in Artificial Intelligence. (Evans and Gazdar, 1996, 166)

The basic idea behind default inheritance is simple and old, dating back to Panini's grammar of Sanskrit: more specific patterns override more general ones. Corbett and Fraser (2000b) use the analogy of a water course diagram to explain the logic behind inheritance hierarchies. The information flows downward from top to the bottom of the hierarchy. Generalizations can be introduced at any level down the structure and trickle downward by default. In a taxonomic account, exceptional facts override generalizations and block them from flowing any further down the structure. The exceptional fact becomes a subgeneralization which flows down to the lower levels. This inheritance is intrinsically nonmonotonic as it allows the flow of information to halt, change and then continue again at any point throughout the structure.

As is customary in explaining the notion of default inheritance, let us look at a non-linguistic example. I borrow the analogy of bird classification from Fraser and Corbett (1995); Corbett and Fraser (2000b).

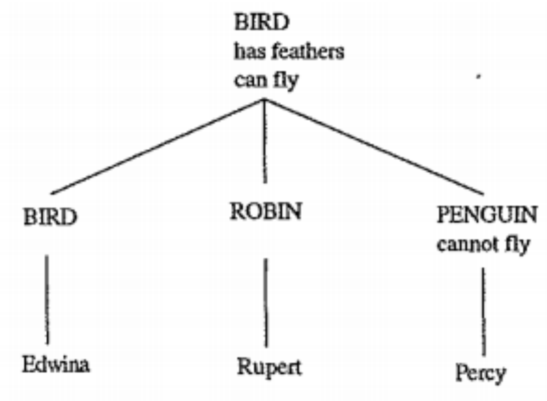


Figure 1.1: BIRD instantiation hierarchy (Fraser and Corbett, 1995, 124)

The lines in this taxonomy indicate instantiation. Default inheritance allows all attributes of a given node in the hierarchy (e.g., BIRD) to be inherited by a node that instantiates it (e.g., EAGLE). This does not happen if a lower node already has an attribute that overrides the default value. In this example, a BIRD has feathers and can fly. All the following nodes inherit these attributes, except for PENGUIN and its instantiation (Percy). Thus, despite the fact that PENGUINs, hence Percy, are BIRDs, they cannot fly.

Notice that the hierarchy used above is a type of subsumptive containment hierarchy that classifies objects from general to specific. This notion of override is pertinent so far as one deals with instantiations and the inheritance of attributes and properties. All the studies that use this mechanism focus in one way or another on linguistic categories and the inheritance of properties. For instance, Corbett and Fraser (2000a) combine Network Morphology and DATR to account for gender assignment in different languages. This is indeed valuable but is totally different from the way monotonicity is being used in the present study. Here, rather than studying instantiations and property inheritance, we abstract away from linguistic forms in paradigmatic cells and use monotonicity as a contour of mappings that involve linguistic hierarchies which are inspired by typological data.

Typological studies of language universals and gaps have been a trend for many years now. Two characteristics set this thesis apart though. First is that it uses two kinds of universals: *language universals* and *linguistic universals*. Cooreman and Goyvaerts (1980) distinguish between the two terms as they represent two different streams of research. The term ‘language universals’ is mostly oriented towards typological analyses of cross-linguistic data, while the term ‘linguistic universals’ is more concerned with theories of Language and the form of grammars (Cooreman and Goyvaerts, 1980, 616). I, thus, use typological cross-linguistic data to arrive at an inventory of attested patterns. Then I examine those patterns to understand their regulatory underlying logic. The cross-linguistic data used in this dissertation is openly accessible on this github directory.[1]

The second distinguishing quality of this thesis is that the type of hierarchies introduced here are independently motivated and cognitively grounded. The tense hierarchy introduced in Chapter 3,

[1] https://github.com/somoradi/somoradi/tree/master/ThesisAppendix

for instance, has a semantic basis that is directly derived from the logical framework that Reichenbach (1947) introduces for temporal relations. I use this kind of logical and metalinguistic explanation for motivating the linguistic hierarchies presented in the thesis to further encourage the approach taken here. I relate these language-independent motivations to Chomsky's (2005) third factors. These are important in that they provide more principled explanation of linguistic phenomena. I briefly discuss the implications of this view in Chapter 6.

Chapters 3, and 4 of this dissertation are revised and expanded versions of the articles I mention in the following summary of chapters. Before introducing the chapters, I invite the interested reader to consider following the flowchart in (1.2) that shows the best way of tackling the chapters of this thesis.

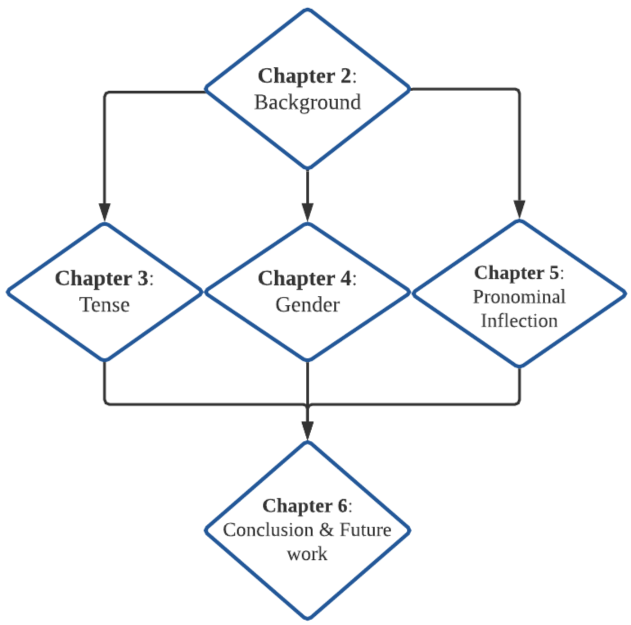


Figure 1.2: How to flow through the chapters of this thesis

I have written the following chapters in a modular way: if you are interested in a specific topic, safely skip other parts but don't miss Chapter 2: Background. To be sure that the reader is able to work through other chapters, I recommend reading the background notions introduced in the second chapter. These include the notion of (feasible) monotonicity, linguistic hierarchies, and a general introduction to the monotonicity framework.

Chapter 3 expands on the approach taken in Moradi (2019) and Moradi (2020). I start by giving a typology of the attested patterns of verb stem syncretism gathered from an opportunity sample of more than 20 languages. I then argue in favor of a non-linear hierarchy of tense motivated based on the logical framework of tense presented in (Reichenbach, 1947). I show that in all of the languages of the sample, the mappings from the tense hierarchy to output forms are monotonic.

Next, in Chapter 4, I explain resolved gender agreement. Part of the data presented here is already published as part of Moradi (2020) and Moradi (2021). In a resolution situation, the properties of two noun phrases are combined to project the gender value of a predicate form. In order to understand the possible types of resolution patterns, I build a logical hierarchy of gender based on the typological data. As predicated, the mappings from the hierarchy to resolved forms are all monotonic.

In Chapter 5, in order to account for the possible patterns of syncretism in person-number combinations, I combine two hierarchies: the person hierarchy and the number hierarchy. This results in six different hierarchies which are all logically possible. The data comes from an extensive typology, including more than 200 languages. Here, instead of postulating one hierarchy for all languages, each language can choose one of the six possible hierarchies. But then, in each language, all the syncretic patterns are monotonic mappings over the chosen hierarchy.

Chapters 3, 4, and 5 thus establish that the seemingly unrelated phenomena of tense syncretism, gender resolution, and verbal inflection obey the same abstract law, which is expressed in mathematical terms as monotonicity. What more, the attested typology is a natural outgrowth of this law because it is applied to linguistically plausible, independently motivated hierarchies. The bewildering range of cross-linguistic variation thus reduces to the interaction of an abstract universal (monotonicity) with linguistic substance (i.e. the hierarchies that must be related by monotonic functions). Not only, then, does this thesis improve on Graf (2019a) by broadening the empirical scope of the framework, but it also shows how specific hierarchies can be linguistically motivated (e.g. the semantic motivation of my tense hierarchy in Chapter 3), and how distinct hierarchies may be combined into new ones (the person-number hierarchies in Chapter 5).

The contrast we see in the treatment of person-number hierarchies (each language chooses one of several possible hierarchies) compared with tense and gender (where every language uses the same universal hierarchy) raises a number of questions. On the one hand, there are questions about the nature of the hierarchies: Should hierarchies be seen as constructs specific to individual languages? How many hierarchies are allowed or are possible? Should we limit hierarchies to specific linguistic branches? On the other hand, there is a basic question about the nature of the monotonicity constraint: Should the monotonicity constraint be seen as a canonical pattern (Corbett, 2007) from which deviations are possible? And finally, if monotonicity is either a hard or a soft constraint, why should it hold?

In Chapter 6 I contrast several possible answers to these questions. The issues are contentious and, to some extent, harken back to the war over linguistic universals in the 50s and 60s. The position I defend builds on the insights gained back then: It is undesirable to force all languages to fit a single frame, but the fact that typologists are able to group languages based on similar traits should also tell us that linguistic variation is not without limit and has its specific ways. The mathematical approach taken here tries to explain the underlying structure of some of our massive linguistic data within a specific framework. If nothing else, this can simply hint at possible language-external ways to understand our cognitive abilities when it comes to linguistic patterns.

Chapter 2

Background

There is a long and interesting history behind the search for characteristics that are common to all languages. Throughout this adventurous history, linguists, both typologists and theoreticians have tried to explore whether typological gaps are systematic or whether each language is a system *sui generis*. This dissertation is an attempt to categorize the range of variations languages show by using an abstract, high-level formal approach that is able to account for seemingly unrelated phenomena using the same underlying logic.

Specifically, I focus on (im)possible patterns in morphology and morphosyntax. I extend Graf's (2019a) monotonicity account within three morphosyntactic domains: verb stem syncretism, resolved gender agreement, and person-number syncretism. The general idea behind this framework is that each morphosyntactic domain comes with a base hierarchy, and the mapping from a hierarchy to surface forms must be order-preserving.

To set the stage for the rest of the thesis, in this chapter, I review some background notions that are required for understanding the idea behind the monotonicity framework. I start by explaining the two fundamental requirements of this approach in the next two sections. In §2.1, I define monotonicity in general terms. This is followed by a more formal discussion on mathematical orders (§2.1.1), monotonic functions (§2.1.2), and the notion of feasible monotonicity (§2.1.3). I conclude this chapter in §2.2 by briefly introducing the monotonicity account of Graf (2019a) and they way it can be used to reframe *ABA and the case hierarchy.

2.1 Monotonicity

Monotonicity works to preserve the underlying order when mapping one object to another. Mapping three objects a, b, and c to the set of three other objects 1, 2, and 3 (with that exact order) is monotonic if, for instance, a goes to 1, b goes to 2, and 3 goes to c. If the mappings for a and c happen the other way round, the resulting pattern is by definition nonmonotonic.

The way autosegmental phonology links tones to a string of segments should come as a familiar example. In autosegmental phonology, structures are usually presented in tiers, and within each tier segments are linearly ordered. The ban on crossing branches assures that all mappings from tones to segments follow the linear order of the two tiers (Goldsmith, 1976).

> Autosegmental phonology is a particular claim, then, about the geometry of phonetic representations; it suggests that the phonetic representation is composed of a set of simultaneous sequences of these segments, certain elementary constraints on how the various levels of sequences can be interrelated –or, as we shall say, "associated." (Goldsmith, 1976, 28)

The most significant and relevant point to our discussion is that association lines that connect vowels and tones do not cross. In this sense, patterns of association in autosegmental phonology are monotonic. The ban against crossing lines ensures that the associations between the two tiers observe linearity, i.e., the linear order of tones follows the linear order of their associated segments.

An example comes from Kikuyu, a Bantu language spoken in Kenya. In (2.1) and (2.2), the upper tier represent segments and the lower tier shows tones.

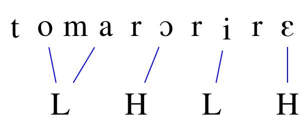


Figure 2.1: Monotonic autosegmental representation in Kikuyu

In (2.1), even though /o/ and /a/ are both associated with L, the patterns show no crossing branches and does not violate monotonicity either, whereas in (2.2), /o/ and /a/ do not preserve their linear order when linking to associated tones. The crossing lines in this case mean that we have a switch in order, which is exactly what monotonicity forbids.

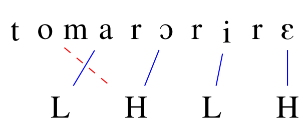


Figure 2.2: Nonmonotonic autosegmental representation in Kikuyu

Going beyond linguistics, let's remember some of our first lessons on math in high school. We would learn about monotonicity in functions with graphs like the ones visualized in (2.3). The graph associated with $f(x) = 2x$ (in blue) is monotonic since in any given point along this graph, the binary relation $\leq$ holds and it does not change direction. Contrast it against $g(x) = x^2$, which is not monotonic because there is a change in direction at the bottom of the graph.

All of the examples I have given you so far are concerned with associations made between totally ordered sets of objects. But what happens with sets where some elements are unordered?

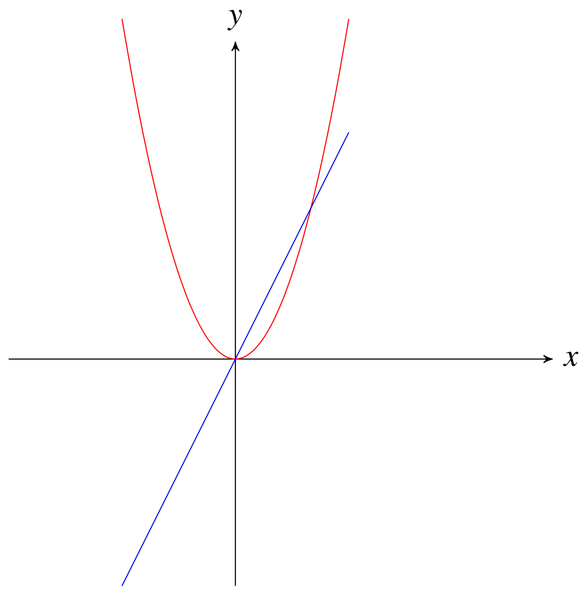


Figure 2.3: $f(x) = 2x$ in blue is a monotonic function; $g(x) = x^2$ in red is nonmonotonic

What does order preservation mean in this case? Assume two sets: $set1 : p, q, r, s$ and $set2 : A, B$. Suppose further that $q \leq r \leq s$, and $q \leq p$, but q is unordered with respect to r and s. Then a monotonic mapping could map p and r to A but q and s to B (2.4).

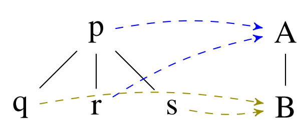


Figure 2.4: Monotonic mappings in a partially ordered structure

In (2.5), if p gets mapped to B while q is still associated with A, then the mappings are no longer monotonic.

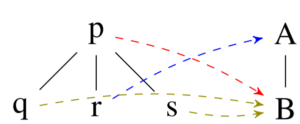


Figure 2.5: Nonmonotonic mappings in a partially ordered structure

This short introduction should be enough to give the reader an overview of how the notion of monotonicity is used in this dissertation. As you can see, monotonicity is a general idea that can work over sets that are either totally ordered or partially ordered.

If you are interested in understanding more about the math behind all this, in the next section I introduce mathematical orders which, as you have already guessed, are required for a definition of monotonicity. They are also important for a better understanding of linguistic hierarchies. After that I move on to formally define monotonicity and feasible monotonicity.

2.1.1 Mathematical orders

In mathematics, orders are special binary relations. Binary relations are exemplified by such ideas as 'is greater than' and 'is equal to' in arithmetic, or 'is an element of' or 'is a subset of' in set theory. The first order that one typically meets in mathematical education is the order $\leq$ of natural numbers, integers, or reals. Another familiar example of an ordering is the alphabetical (lexicographic) order of words in a dictionary.

Consider some set A and a relation $\leq$ on A: $\leq$ is a partial order if it is reflexive, antisymmetric, and transitive, i.e., for all a, b, and c in A, we have:

- $a \leq a$ (reflexivity)
- if $a \leq b$ and $b \leq a$, then $a = b$ (antisymmetry)
- if $a \leq b$ and $b \leq c$, then $a \leq c$ (transitivity)

A set with a partial order on it is called a *partially ordered set*, *poset*, or just an ordered set. The orders on natural numbers, integers, rational numbers and reals are all orders in this sense in addition to an additional property of being total, i.e., for all distinct a and b in A, we have that:

- $a \leq b$ or $b \leq a$ (totality)

These orders are also called *linear orders* or chains. In this thesis, we will encounter some linear orders (e.g. gender hierarchies in §4), but the majority of hierarchies will be partial orders that are not total, which is to say, some elements of the hierarchy won't be ordered with respect to each other.

Before moving on to the next section to define monotonicity, I want to briefly go over two order-theoretic topics that are related to our discussion.

First, in order to make formal representations easier, it will be helpful to display orders in a convenient graphical way. For this purpose we use a variation of Hasse diagrams. These are graphs where the vertices are the elements of the poset and the ordering relation is indicated by both the edges and the relative positioning of the vertices (see Figure 2.6). Concretely, one represents each member of a set S as a vertex on the page and draws a line that goes downward from x to y if $x < y$, and there is no z such that $x < z < y$. Furthermore it is required that the vertices are positioned in such a way that each line meets exactly two vertices: its two endpoints.

The second topic to briefly cover is constructing new orders from existing orders. One way to do this is by inverting the ordering: A given order can be inverted by reversing its direction; pictorially, flipping the Hasse diagram top-down. This yields the so-called dual, inverse, or opposite order. Another way of constructing a new order is the Cartesian product of two partially ordered sets, together with the product order on pairs of elements.

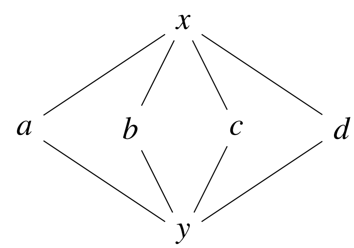


Figure 2.6: an example of a Hasse diagram

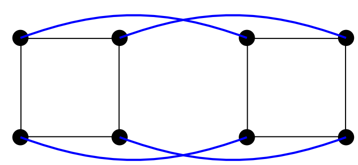


Figure 2.7: A Cartesian product of graphs

The Cartesian product of two sets A and B, denoted $A \times B$, is the set of all possible ordered pairs whose first component is a member of A and whose second component is a member of B: $A \times B = \{(a,b) \mid a \in A \text{ and } b \in B\}$. Based on this, we can get a new order from the original orders by setting $(a,x) \leq (b,y)$ if $a \leq b$ and $x \leq y$. I will use this method to construct a hierarchy of person-number using the existing orders for person and number (Chapter 5).

2.1.2 Monotonic functions

Functions between (partially) ordered sets have certain properties that are related to the ordering relations of the two sets between which the function is operating. The most fundamental condition that occurs in this context is monotonicity. In mathematics, functions between ordered sets are monotonic if they preserve the given order.

Definition 1 (Monotonicity)**.** Let f : $A \rightarrow B$ be a function and let $\leq_A$, $\leq_B$ be partial orders on sets A and B, respectively. Then: $\forall x,y \in A, x \leq_A y$ implies $f(x) \leq_B f(y)$.

The definition can be restated more colloquially as follows: Suppose that f is a function between two sets, which we call A and B. Each set has a partial order defined over it, making it a poset. The function f is monotonic iff it holds that whenever $x \leq y$ in A, it must be the case that $f(x) \leq f(y)$ in B. Stated differently, a monotonic function must preserve the existing ordering statements between elements (unordered elements, however, are immaterial for monotonicity).

The definition above actually describes a special case of monotonicity, known as monotonic increasing or *isotonic*. Its counterpart is the property of being monotonic decreasing or *antitonic*: if $x \leq_A y$, then $f(x) \geq_B f(y)$. Every monotonic decreasing function can be made monotonic increasing by reversing the order of elements in B. That is to say, if $x \leq_B y$, one instead assumes

$y \leq_B x$. Since the orders and hierarchies discussed in this thesis have no natural top or bottom, there are no linguistic repercussions to reversing them in this manner. For this reason, it suffices to consider only monotonic increasing functions, and for the sake of brevity I will simply refer to them as monotonic functions throughout the thesis.

Suppose A is the set of non-negative integers ordered in the usual fashion, i.e., 0, 1, 2, 3, and so on. And let B be a set of names in alphabetical order. For this example, let us assume that B is *Armina*, *Mehrad*, *Paniz*. There are infinitely many functions from A to B, that is to say, infinitely many ways to map each positive integer to one of the names in B. But only a fraction of these functions are monotonic.

Consider first the function f which maps 0 to *Armina*, all odd numbers to *Mehrad*, and all even numbers to *Paniz*. This function is not monotonic. We prove this by showing that there are two integers x and y such that x is ordered before y yet $f(x)$ (i.e. one of our three names) is not ordered before $f(y)$ (which is also one of our three names). A concrete instance of that is $x = 6$ and $y = 7$. Clearly $x \leq y$, yet $f(x) = \textit{Paniz}$ is alphabetically after $f(y) = \textit{Mehrad}$. Hence we have $x \leq y$ but not $f(x) \leq f(y)$, violating monotonicity. This is also shown in (2.8) on the left.

Now contrast this against the function g which maps 0 to *Armina*, all numbers from 1 to 7 to *Mehrad*, and all other non-negative integers to *Paniz*. This is a monotonic function — no matter how hard we try, there is no choice of x and y such that $x \leq y$ but not $g(x) \leq g(y)$. We have to consider several cases depending on the value of x. Suppose x is 0, so that $g(x) = \textit{Armina}$. No matter how we pick y, it must be the case that $x \leq y$ because there is no non-negative integer that is less than 0. But for the same reason, it must also be the case that $g(x) \leq g(y)$ because our list of names contains no name that is ordered before *Armina*. Now suppose that x is 1, so that $g(x) = \textit{Mehrad}$. If $x \leq y$ holds, then $y \geq 1$. But then $g(y)$ is either *Mehrad* or *Paniz*, which implies $g(x) \leq g(y)$. The very same reasoning can also be used to show that monotonicity is not violated for any choice of $x \geq 2$. In contrast to f above, then, g is indeed a monotonic function from the set of non-negative integers, ordered by $\leq$ in the usual fashion, to our list of names in lexicographic order.

As these examples show, verifying a function's monotonicity requires more work than showing that it is not monotonic. However, there is an easy visual intuition. Look at (2.8) and contrast the non-monotonic function f on the left against the monotonic function g on the right. Whereas f contains crossing lines, g does not. This is a visual indicator of non-monotonicity.

(1) Visual indicator of non-monotonicity
If the mapping between two linear orders contains crossing branches, it is not monotonic.

With a firm understanding of monotonicity under our belt, we are almost ready to discuss the monotonicity framework of Graf (2019a). However, we still need to make one minor tweak to our notion of monotonicity. Many linguistic phenomena involve mappings from an ordered linguistic hierarchy — e.g., the adjectival degrees positive, comparative, superlative — to a seemingly unstructured set, e.g., the collection of surface forms *good*, *better*, *best*. But monotonicity as commonly defined

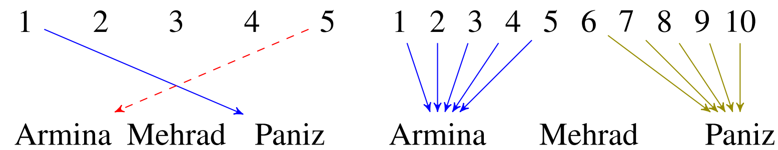


Figure 2.8: Crossing lines shows nonmonotonicity.

requires both structures to be ordered, just one poset is not enough. The notion of *feasible monotonicity* in Graf (2019a) is explicitly designed to address this issue, and plays a crucial role in his treatment of *ABA phenomena (see §2.2.1).

2.1.3 Feasible monotonicity

An important part of Graf's account (2019a) is that, in addition to the base hierarchy of a linguistic phenomenon, the output forms should also be strictly ordered in order to invoke monotonicity. This does not happen in all situations. Consider once more the example of adjectival gradation. The degrees of adjectives can be linguistically motivated to have the following order: *positive* $<$ *comparative* $<$ *superlative*. The same does not hold for a set of surface realizations of those degrees, e.g., *big*, *bigger*, *biggest*. Since there is no logical way to order the three forms of the adjective *big*, Graf (2019a) proposes the notion of feasible monotonicity.

Definition 2 (Feasible monotonicity)**.** Let A be a set ordered by $\leq_A \subseteq A \times A$, and B some arbitrary set. Then $f : A \to B$ is *feasibly monotonic* iff there exists at least one ordering $\leq_B \subseteq B \times B$ such that f is monotonic with respect to $\leq_A$ and $\leq_B$.

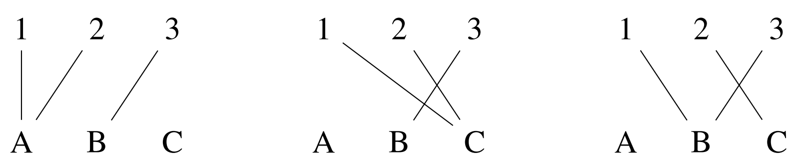


Figure 2.9: Monotonic, feasibly monotonic, and nonmonotonic mappings

Simply put, a function is feasibly monotonic iff there is a way of ordering its co-domain that makes the function monotonic. Let's consider the three mappings shown in (2.9). The mapping on the left is monotonic. The one in the middle is not monotonic, but it is feasibly monotonic because we can switch the order of B and C and obtain a monotonic mapping. The one on the right is neither monotonic nor feasibly monotonic: no ordering of A, B and C will result in non-crossing lines. In other words, the $\times$-like association between the two sets will not resolve no matter how one orders the elements.

> [M]onotonic mappings are order-preserving in the sense that they do not invert existing orderings: $x \leq_A y$ entails $f(x) \leq_B f(y)$. The notion of feasibly monotonic mappings

> extends this to cases where the co-domain lacks internal structure. It does so by considering all possible ways to order the co-domain such that feasible monotonicity holds iff monotonicity holds for at least one of those orders. (Graf, 2019a, 9)

Feasibility in this sense is a minor adjustment to the notion of monotonicity which makes for a more accessible way of interpreting different patterns we come across. This definition of feasible monotonicity allows partial orders, but both in Graf (2019a) and in here, it is used with linear orders. It might seem that a more restricted definition is a better fit for the current data, I leave it as flexible, however, to account for possible additions to the data and analysis. We will see this at work in 2.2.1. In the next section, I put together all the formal insights I have discussed so far to arrive at the monotonicity framework (Graf, 2019a).

2.2 Monotonicity framework

The goal of understanding the underlying systematicity of language structure is more attainable if the complicated and idiosyncratic details are abstracted out of paradigms, allowing us to see the interaction of general principles. In the same spirit, Graf (2019a) uses a high level of abstraction in the framework he develops to account for typological gaps in certain areas of morphology and morphosyntax. In each domain, the goal is to understand —and possibly give a unifying explanation to this question: why not all logically conceivable patterns are attested.

This account derives typological gaps in morphological paradigms from two components. First is an underlying hierarchy of the phenomenon at hand (e.g., person hierarchy, case hierarchy, etc.). Second are the mappings from this underlying hierarchy to output forms which should all observe monotonicity. In each linguistic domain, "the shape of the base hierarchy and the monotonicity requirement conspire to greatly limit the range of possible patterns." (Graf, 2019a, 4)

Graf (2019a) has successfully used the monotonicity account as an abstract condition on morphological paradigms to explain typological gaps in adjectival gradation, case syncretism, pronoun syncretism, the Person Case Constraint, and the Gender Case Constraint. He also extends the notion into syntax. In Graf (2020), he covers a range of syntactic constraints in terms of monotonic functions that map specific kinds of syntactic representations to fixed, universal hierarchies. These constraints include the Ban Against Improper Movement, the Williams Cycle, the Ban Against Improper Case, and omnivorous number.

To better understand this approach, next I will go over the monotonic nature of the *ABA generalization in adjectival gradation.

2.2.1 *ABA in adjectival gradation

The *ABA generalization, assumes that with a linear order of paradigm cells, two cells cannot be homonymous to the exclusion of any intervening cells. Bobaljik (2012) is the most influential account of *ABA, even though the idea has been explored before him as well (e.g., Wiese (2005), Bonami and Boyé (2002)).

With a positive-comparative-superlative order in adjectival suppletion, Bobaljik (2012) shows that one cannot find an ABA pattern, where the positive and superlative share a root distinct from the comparative (Table 2.1).

LANGUAGE	POSITIVE	COMPARATIVE	SUPERLATIVE	PATTERN
Persian	**xub**	**xub**tar	**xub**tarin	AAA
English	good	**be**tter	**be**st	ABB
Latin	bonus	melior	optimus	ABC
*Latin	bonus	melior	*bonissimus	*ABA

Table 2.1: Adjective suppletion patterns

Bobaljik (2012) accounts for *ABA in terms of feature containment. Within the Containment Hypothesis (Bobaljik, 2012, 7), this gap is due to the fact that a superlative morpheme does not directly attach to the root of an adjective. Rather, the representation of the superlative properly contains that of the comparative (2).

(2) a. Positive: [ADJECTIVE]
b. Comparative: [[ADJECTIVE] COMPARATIVE]]
c. Superlative: [[[ADJECTIVE] COMPARATIVE] SUPERLATIVE]]

Graf (2019a) shows that *ABA is an instance of monotonicity. Irrespective of whether $A \leq B$ or $B \leq A$, it is impossible for a monotonic function to ever map positive-comparative-superlative to ABA. In that case, we have $f(positive) = A = f(superlative)$. If $A \leq B$, then the fact that $comparative < superlative$ implies that $f(comparative)$ must be A if f is monotonic — if it were B, then we would have $comparative < superlative$ yet $f(comparative) = B \not\leq A = f(superlative)$. If, on the other hand, we have $B \leq A$, then $f(comparative) = A$ follows from $positive < comparative$. Either way it is impossible for a monotonic function to map comparative to any value other than A.

This example highlights yet another way of thinking about monotonicity.

(3) *Monotonicity as an interval restriction:*
Whenever a monotonic function maps two values x and z to the same value V, every y between x and z is also mapped to V.

This is similar to the non-crossing constraint in autosegmental phonology, a case I discussed earlier (2.1).

Even though this constraint is associated with Bobaljik's work, *ABA had already been observed by other linguists prior to his work as well. In their discussion of simple stem dependency in the present paradigm of French verbs, Bonami and Boyé (2002) explain that, following Morin (1987), they have found "no verb in French which has the same stem for the imperfective and for the present singular, but has a different stem for the present third plural." This is shown in Table 2.10. The third row of this table is indicated by an asterisk, showing an unattested ABA pattern. They account for this by postulating a dependency relation between the three stems: "The present third plural is either suppletive or identical with the imperfective; and the present singular is either suppletive or identical with the present third singular" (Bonami and Boyé, 2002, 6). The morphology of verbs will also be the subject of Chapter 3 of this dissertation.

	imperf./prst. 12pl	prst. 3pl	prst. sg
laver 'wash'	lav A	lav A	lav A
savoir 'know'	sav A	sav A	sɛ B
*	* A	* B	* A
mourir 'die'	mur A	mœr B	mœr B
boire 'drink'	byv A	bwav B	bwa C

Figure 2.10: Stem slots in the present paradigm of French verbs (Bonami and Boyé, 2002, 7)

Corbett (1979) shows the *ABA generalization in a different way. The basic claim of the Agreement Hierarchy is that if semantic agreement is available at any position on the hierarchy, it must be available at all positions to the right.

(4) The Agreement Hierarchy (Corbett, 1979):
attributive > predicate > relative pronoun > personal pronoun

The constraining effect of the hierarchy is illustrated in (2.11). In this illustration, filled squares show semantic agreement. The four columns represent the four parameters of the hierarchy: attributive, predicative, relative pronouns, and personal pronouns. Take the first row where the four parameters are represented as □ □ □ □. Let's read this as an AAAA pattern. The second line is □ □ □ ■. This is an instance of an AAAB pattern. Likewise, here are the patterns for the third and fourth rows: AABA (unattested), AABB (attested).

Attested patterns of the Agreement Hierarchy show that eleven of the theoretically possible sixteen situations are ruled out. Corbett does not talk about ABA in his discussion of these agreement patterns, but we can see that the patterns and their presentation show a similar idea: None of the instances of an ABA ordering are attested. Corbett, however, does explore the monotonic relations that these patterns show: "The possibility of syntactic agreement decreases monotonically from

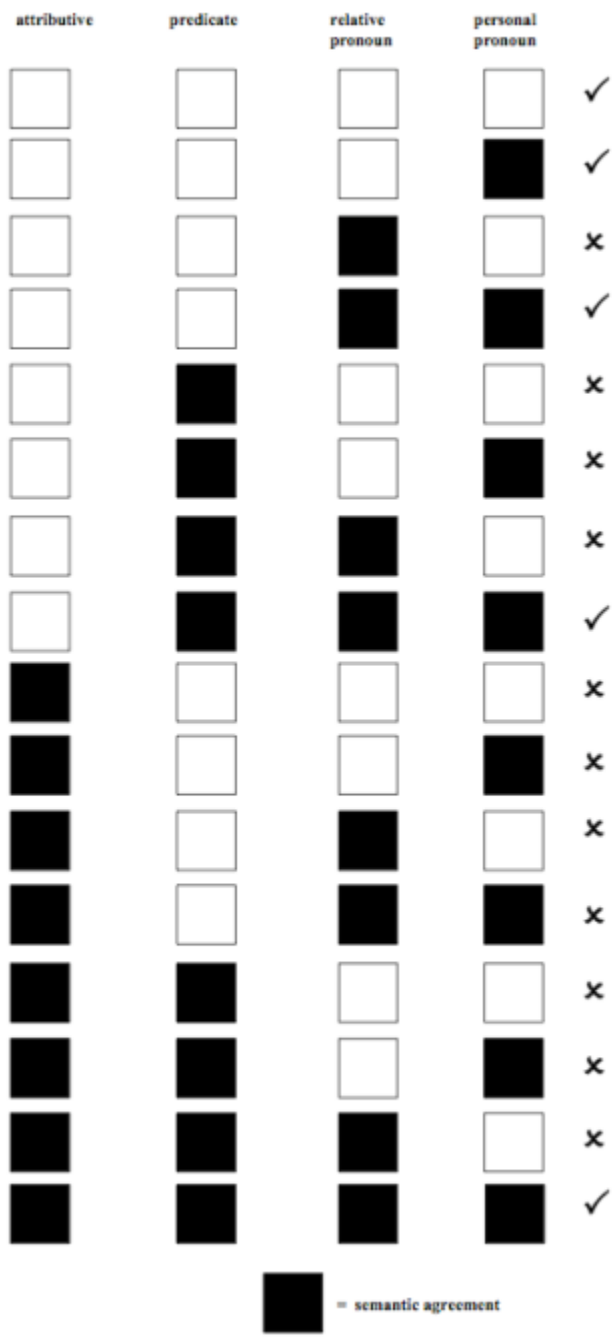


Figure 2.11: Systems allowed by the Agreement Hierarchy (Corbett, 2011, 5)

left to right. The further left an element on the hierarchy, the more likely syntactic agreement is to occur, the further right, the more likely semantic agreement" (Corbett, 1979, 204). This supports the prevalence of ways one could use to account for linguistic observations using monotonicity.

2.2.2 Partially ordered case hierarchies

The *ABA generalization has also been found in other domains of morphology, like pronominal suppletion and case systems. Smith et al. (2016) and Harbour (2015) show that languages with pronouns may use the same pronoun for all person values (AAA), or they may have the same form for the first and second (AAB), or the second and third persons (ABB), or simply have separate forms for all three persons (ABC), but they will never use the same pronoun for the first and third persons (*ABA).

In Caha's arrangement of the case order (Caha, 2009), the representation of Genitive properly contains that of Accusative, which in turn properly contains Nominative, etc. (Nominative $<$ *Accusative* $<$ *Genitive* $<$ *Dative* $<$ Instrumental). Thus, for example, Accusative and Dative cannot be syncretic to the exclusion of Genitive (*ABA).

According to Caha's linear case hierarchy, accusative and genitive can be syncretic while nominative and genitive cannot (Caha, 2009, 11). In fact, in a strictly linear order many attested patterns of syncretism violate the proposed *ABA. (The same problem happens with a linear approach to tense as I explain in §3.2.2.) Bárány (2018), for instance, shows that in Spanish accusative and dative can be syncretic and Caha's account does not capture this. Additionally, Harðarson (2016), Starke (2017), Zompì (2019), and Irimia (2020) have addressed Caha's account showing data that disputes the position of genitive in the case sequence and have proposed having multiple positions for the genitive case as a possible consolidation (Starke, 2017).

Among others, Zompì (2019, 23) advocated for a hierarchy that orders classes of cases, rather than cases themselves, with respect to each other (Clausal unmarked $\subset$ Clausal dependent $\subset$ Inherent). Building upon that approach, Graf (2019a) and Bárány (2021) propose conceiving a case sequence not as a total order, but as a partially ordered set (or poset) such that not all elements of the case hierarchy need to be ordered with respect to each other.

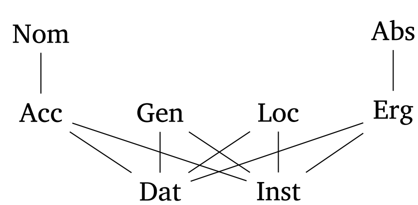


Figure 2.12: Case hierarchy based on Graf's account (2019a)

This partial hierarchy includes three case layers with special status granted to genitive and dative. The syncretism of accusative and dative to the exclusion of the genitive in Germanic languages

Harðarson (2016), which is problematic for Caha's account, then would be readily explained by the fact that genitive is unordered with respect to nominative and accusative.

The hierarchy also allows nominative-accusative-dative syncretism, but not nominative-ergative-dative. The monotonicity requirement only allows syncretism of nominative and one of the oblique cases if it also includes accusative. Yet it is possible to get the attested syncretism of nominative and ergative to the exclusion of accusative. Generally, if the *ABA requirement over a linear order is generalized to a monotonicity requirement over a partial order, all the attested patterns of case syncretism can be accounted for in terms of Graf's monotonicity framework.

The next three chapters of this dissertation demonstrate the power of this formal requirement in different areas of morphosyntax. As a continuation of our discussion on *ABA and its implications, I start with typological data on tense-stem syncretism (Chapter 3) before moving on to resolved gender agreement (Chapter 4) and person-number syncretism (Chapter 5). With only three tenses (present, past, participle), a *ABA type of constraint can predicate the typological gaps in the data. If the future stem is also added though, we will find attested patterns that violate *ABA. One way to accommodate the data is to have several positions for the future, the same proposal that was discussed with respect to genitive in the case hierarchy. The analysis presented in Chapter 3 is that there is a partial hierarchy of tense that is independently motivated by Reichenbach's framework (Reichenbach, 1947). Over this hierarchy, all the attested patterns of syncretism are monotonic.

Chapter 3

Tense Syncretism

The first of the three morphosyntactic phenomena analyzed in this dissertation is tense and its morphological expression. I extend the existing work on *ABA generalization in verbal paradigms and show how monotonicity restricts the ways in which verbal forms can or cannot be similar. In doing so, I employ a diverse set of data from more than 20 languages (§3.2) and show that, with a linear ordering of verbal roots in morphological paradigms, the ban on ABA patterns will be violated (§3.2.2). Such patterns can instead be accounted for by the mathematical notion of monotonicity that preserves the hierarchical structure of the tenses. The proposed hierarchy of tense is independently motivated by a logical model of time which is based on the interaction of speech time, event time, and reference time (Reichenbach, 1947). The conceptualization of time in this sense is common among all the studied languages and signifies the monotonicity restriction on the morphology of tense.

3.1 *ABA in tense morphology

All across Indo-European languages, 'principal parts' describe the basic forms of a verb including the base or infinitive. In these languages, there are three general tenses: the past, the present and the future. This results in four verbal tense-stem principal parts.

I. The present stem

II. The past/aorist stem

III. The perfect stem, giving the perfect, only later specialized in present, past or future.

IV. The future stem

The stem in each case is a combination of the verbal root and possibly a morphological marker. In English, for instance, the stems for the base *walk* would be: *walk, walked, walked, walk*. For the so-called ‘irregular’ verbs, though, things are somewhat different. We can have verbs bases like *fly*: *fly, flew, flown, fly*: I can *fly* the kite by myself. I *flew* the kite by myself. I have *flown* the kite by myself before. I *will fly* the kite in June. There are other examples of this kind, *feel-felt-felt-feel, come-came-come-come, go-went-gone-go*, etc.

Similar irregularities, or variations, are found not only in other Indo-European languages, but in other language families as well. In a four-cell paradigm of verb stems, then, what kinds of combinations are allowed and which orderings are not seen across languages? In order to answer this question, I start by trying to fit the data within the *ABA account (Bobaljik, 2012). As discussed in (§2.2.1), the main idea of this account is that with a linear order of paradigm cells, two cells cannot be syncretic to the exclusion of any intervening cells. This is a great start, but as we will see, tense requires an account that goes beyond linear ordering: No matter how we order the four tenses linearly, we get patterns that violate *ABA (§3.2.2).

While Bobaljik is mostly concerned with the absence of ABA patterns in adjectives, he also briefly discusses tense syncretism in verb forms. He draws on Wiese’s (2005) analysis of ablaut in German verbs to explain German stem alternations within the same framework. Wiese’s work includes 40 distinct attested patterns for German principal parts, i.e., the present, the preterite (simple past), and the perfect participle (Wiese, 2005, 2). The 40 patterns are gathered based on the general characteristics of vowel alternation of their stems as described in (5) and testified by examples from German in Table 3.1 (Bobaljik, 2012, 233).

(5) a. Distinct for all three principal parts.
b. Past and perfect participle identical, present distinct.
c. Present and perfect participle identical, simple past distinct.
d. Unattested: present and past identical, participle distinct.

PRS.1SG	PRF PRTCPL	PST.3SG	PATTERN
sprech-e	ge-sproch-en	sprach	ABC
gieβ-e	ge**goss**en	**goβ**	ABB
geb-e	ge-**geb**-en	gab	AAB

Table 3.1: Verb suppletion patterns in German

Bobaljik (2012, 234) extends this presentation of verb stem alternations to English verbs. He notes that verb in English and German do not display ABA patterns if one assumes an order of Present-Perfect Participle-Past (3.2). This is an example of the sort of monotonicity that Graf discusses, where one can find a monotonic order, though not one grounded in any independent criteria.

Wiese (2005, 29) and Bobaljik (2012, 234) explain the gap in the data, i.e., the unattested identicality of present and past to the exclusion of participle, using the Containment Hypothesis within the hierarchy in (6).

PRS.1SG	PRF PRTCPL	PST.3SG	PATTERN
sing	sung	sang	ABC
shine	**shone**	**shone**	ABB
come	**come**	came	AAB
walk	**walk**ed	**walk**ed	AAA

Table 3.2: Verb suppletion patterns in English

(6) Present < Perfect Participle < Past

(7) a. Present: []
b. Participle: [[] PAST]]
c. Past: [[[] PAST] FINITE]]

In this feature embedding hierarchy of tenses (7), the present tense is the default with no feature specifications. The features [FINITE] and [PAST] are associated with past and past participle, respectively Bobaljik (2012, 235). Furthermore, the representation of the past properly contains that of the participle. ABA patterns do not occur because the feature embeddings implied by the linear hierarchy in (6) prevent them.

Bobaljik's approach makes two predictions under the natural assumption of a single containment hierarchy for tense: (i) present and past are never syncretic to the exclusion of participle, and more generally (ii) all tenses can be linearly ordered across languages so that no ABA patterns ever arise. In what follows, I show that Bobaljik's prediction is only partially borne out once one considers a wider range of data: ABA patterns do arise, but only if one also considers future tense. This is problematic for Bobaljik's system, even though one could argue for multiple positions of the future within the hierarchy (similar to the locus of genitive in a case hierarchy briefly discussed in 2.2.2). The problem can be readily explained via a partial order of morphological tenses within the monotonicity framework of Graf (2019a). Crucially, this partial order is induced by the tense system of Reichenbach (1947) and thus arises from third factor principles (Chomsky, 2005).

In the rest of this chapter, I present the cross linguistic data and the 10 possible alternations they demonstrate in §3.2, and explain why a *ABA restriction over a linear order cannot account for all types of verbal stem alternations. Then, drawing on Graf's (2019a) reanalysis of the *ABA generalization as an outcome of monotonicity in §2.1, I introduce monotonicity as the restriction on a partial hierarchy of tense. In §3.3, I show that this hierarchy is independently motivated by Reichenbach's tense system. §3.4 concludes the paper and summarizes how monotonicity can reinterpret the *ABA generalization and build a formal upper bound on the range of typological variations.

3.2 Data and Analysis

The results reported here are based on a typologically diverse opportunity-sample of tense syncretism in more than 20 languages, drawn from Altaic, Germanic, Indo-Iranian, Romance, and Slavic, among others.

At the outset, I explain the methodology I have used to gather the data (§3.2.1). Then we will see the inventory of attested patterns in §3.2.2. I go over the analysis of the data based on the monotonicity requirement in §3.2.3.

3.2.1 Methodology

The data reported here is gathered mainly by consulting individual informants. In individual interviews, I asked informants to either fill out conjugation tables or come up with the right form of a verb in hypothetical narratives. To suit the research question which deals with the four tense-stems, I was mainly concerned with languages where one can find the present, past, future, and participle stems. Many of the languages I recorded would not show all the stems and as a result are not included in the study. Languages like Korean without a participle stem form an exception.They are included since they do show the three relevant tenses (present, past, future). Admittedly this requirement will restrict the representativeness of my sample of languages. What I gathered, however, is a rather inclusive sample among the languages that meet our requirement.

A stem can be a single root or more than a root. A situation where paradigms do not use the same stem throughout is called suppletion. To make this clear, let's look at some examples. The first example comes from Persian (8).

(8) a. **xor**.PRS – **xor**d.PST – **xor**de.PRTCPL 'eat'
b. bin.PRS – **did**.PST – **did**e.PRTCPL 'see'

The root of the verb in the first row of (8) is *xor* all through the paradigm, however, there are two stems present: *xor* and *xord*. In the second row, there are two roots and two stems: *bin* and *did*.

Next, look at the Italian verb *andare*, where the distribution of two stems is phonologically determined. *va(d)-* is used in forms where the stem is stressed, while *and-* is used elsewhere. So, the present subjunctive emerges as (9):

(9) vád-a, vád-a, vád-a, and-iámo, and-iáte, vád-ano 'go'

The focus of this study is on such types of suppletion. Thus, in languages which distinguish between the two, the material we use is the verb root rather than the verb stem. French gives us one final example to clarify this point. Table 3.3 shows the conjugation of the verb *aller* 'go'.

	SG	PL
1	vais	allons
2	vas	allez
3	va	vant

Table 3.3: Partial conjugation of the French *aller* 'go'

Even though there might be more than one stem in the conjugation of *aller*, there are two roots: *va* and *al(l)*. In the rest of this section, roots are the factor behind tense alternations and the resulting patterns. We won't arrive at the same patterns, should we decide to use stems rather than roots. Whether stems reveal comparable patterns and analysis is a topic for future work.

3.2.2 Patterns of tense syncretism

In 15 of the languages under investigation, the root does not change no matter what the tense is. Apparent instances of this type are Semitic languages where the root is consistent all through the paradigm.[1] Of course, this interpretation is on the right track only if one takes the root as a sequence of consonants, which would result in actual words by adding templatic vowels and non-root consonants.[2]

(1) *All Stems have the Same Root*

Language	Past	Participle	Present	Future	Gloss
Arabic, MS	**ʔkal**-a	–	ja**ʔkul**-u	sa ja**ʔkul**-u	eat
Azeri	**gæl**dı	**gæl**miʃ	**gæl**ir	**gæl**æçæx	come
Korean	**pone**tta	–	**pone**ta	**pone**l kʌʃita	send
Turkish	**gel**di	**gel**miʃ	**gel**ijor	**gel**eçek	come

Other languages showing this pattern include Urdu, Gujrati, Sindhi (Indic); Persian, Laki (Iranian); English, German (Germanic); French, Spanish, Italian (Romance); Armenian (Western and Eastern); and Russian.

The second most frequent pattern found in the data is when past and participle share the same root, while present and future use an identical root. Japanese; Urdu, Gujrati, Sindhi (Indic); Kurdish, Laki (Iranian); English (Germanic); French, Italian (Romance); Armenian (Western and Eastern) are among the languages that show this pattern.

[1] In Modern Hebrew, there are two verbs for 'say': *amar* and *higid*. Although each verb has its own full paradigm, it was shown that these two stems alternate according to tense and mood (Brown et al. 2003).

[2] In what follows, the term 'Participle' is used as a short form for the 'Past Participle'.
The cross-linguistic data presented below is also available at
https://github.com/somoradi/somoradi/tree/master/ThesisAppendix

(2) *Same Root for Past and Participle; Same Root for Present and Future*

Language	Past	Participle	Present	Future	Gloss
Japanese	**ʃit**a	**ʃit**eita	**suru**	**suru**	do
Western Armenian	**ger**a	ger-ad͡z@[3]	g**ud**e	bidi **ud**e	eat

The rest of the patterns are much less common than the first two. The languages associated with each pattern are listed below.

(3) *Same Root for Past, Participle and Future; Separate Root for Present*

Language	Past	Participle	Present	Future	Gloss
Persian	**did**	**did**e	**bin**	xɑhad **did**	see
Serbo-Croatian	**hte**o sam	**hte**o	**ho**ću	**hte**ću	want

(4) *Distinct Roots for all Stems*

Language	Past	Participle	Present	Future	Gloss
Italian	diss[4]	detto	diç[5]	dir	say
German	warf	geworfen	wirf[6]	werfen	throw
French	fu	été	suis.1SG	ser	be

(5) *Same Root for Past and Participle; Distinct Roots for Present and Future*

Language	Past	Participle	Present	Future	Gloss
SerboCroatian	**iʃa**o sam	**iʃa**o	idem	ići ću	go
Sindhi	**wa**yo	**wa**yo ho	wanje t^{h}o	wiindo	go
Southern Kurdish	**ber**d	**beri**ɑ	beid	bad	carry

(6) *Same Root for Past, Participle and Present; Separate Root for Future*

Language	Past	Participle	Present	Future	Gloss
French	**all**	**all**	**all**[7]	ir	go

(7) *Same Root for Present and Future; Distinct Roots for Past and Participle*

Language	Past	Participle	Present	Future	Gloss
Kurdish	xwɑrd	xoriɑ	**xweid**	**xweid**	eat

(8) *Same Root for Participle and Future; Distinct Roots for Past and Present*

Language	Past	Participle	Present	Future	Gloss
German	gab	ge**geben**	gib[8]	**geben**	give
Spanish	fu	∅i	v	∅ir	go

(9) *Same Root for Participle, Present and Future; Separate Root for Past*

Language	Past	Participle	Present	Future	Gloss
English	went	**go**ne	**go**	will **go**	go

(10) *Same Root for Participle and Present; Distinct Roots for Past and Future*

Language	Past	Participle	Present	Future	Gloss
French	vin	**ven**	**ven**[9]	viend-r	come

The variety of ways verb roots are paradigmatically related vary a lot, even within a language. The language sample I studied rendered the following 10 patterns of verbal syncretism.

	Pattern Description	Linear Order
1	All Stems have the Same Root	AAAA
2	Past = Perfect Participle; Present = Future	AABB
3	Past = Perfect Participle = Future; Separate Root for Present	AABA
4	Distinct Roots for all Stems	ABCD
5	Past = Perfect Participle; Distinct Roots for Present and Future	AABC
6	Past = Perfect Participle = Present; Separate Root for Future	AAAB
7	Present = Future; Distinct Roots for Past and Perfect Participle	ABCC
8	Perfect Participle = Future; Distinct Roots for Past and Present	ABCB
9	Perfect Participle = Present = Future; Separate Root for Past	ABBB
10	Perfect Participle = Present; Distinct Roots for Past and Future	ABBC

Table 3.4: Description of Attested Patterns with PST-PRF-PRS-FUT order

In order to better understand the nature of the attested patterns and anticipate the kind of hierarchy we need, let's take a look at the unattested patterns. The total number of possible patterns for a paradigm with 4 cells is 15 (Bell number of 4), from which we already have 10. The remaining 5 unattested patterns are the following.

	Pattern Description	Linear Order
(1)	past = present; participle = future	ABAB
(2)	past = future; participle = present	ABBA
(3)	past = present = future; Separate root for participle	ABAA
(4)	past = present; Distinct roots for participle and future	ABAC
(5)	past = future; Distinct roots for participle and present	ABCA

Table 3.5: Description of Unattested Patterns with PST-PRF-PRS-FUT order

Out of all logically possible patterns, only 5 are unattested: ABAX (where Future is A, B, or C), ABBA, and ABCA. The absence of ABAX patterns shows that syncretism of Present and Past

[4] The derivational segment can also include *-a* or *-t*.
[5] Another form of the past stem of this verb is *diç-*.
[6] Another form of the present stem of this verb is *werf*.
[7] Another form of the present stem of this verb is *v-*.
[8] Another form of the present stem of this verb is *geb-*.
[9] Other forms of the present stem of this verb are *vien-* and *viennent*.

to the exclusion of Participle is not attested.[10] The behavior of Future is problematic, though. While Future is never syncretic with Past to the exclusion of either Present or Participle, AABA and ABCB violate the *ABA generalization. But if one allows for partial orders, ABA patterns with Future can be accounted for in terms of the monotonicity constraint (Graf, 2019a).

Note that the step from a linear order to a partial one is indeed necessary as there is no way of totally ordering all four tenses such that there are no ABA configurations. Consider the attested pattern where past, participle and future are syncretic to the exclusion of present, as is the case in Persian and Serbo-Croatian. This pattern will be AABA with a PST-PRF-PRS-FUT ordering and ABAA with a PST-PRS-PRF-FUT ordering, both of which violate the ABA generalization. Our linear order won't violate *ABA if and only if it posits present at either end of the order. But any such order will be problematic for other attested patterns leading to the violation of *ABA. I have shown this in Table 3.6.

Linear Order	Example of an attested pattern violating *ABA	
PRS-PRF-PST-FUT	Participle = Present = Future; Separate Root for Past	AABA
PRS-PRF-FUT-PST	Present = Future; Distinct Roots for Past and Participle	ABAC
PRS-PST-PRF-FUT	Participle = Present = Future; Separate Root for Past	ABAA
PRS-PST-FUT-PRF	Past = Participle; Present = Future	ABAB
PRS-FUT-PST-PRF	Participle = Present = Future; Separate Root for Past	AABA
PRS-FUT-PRF-PST	Participle = Present; Distinct Roots for Past and Future	ABAC
PST-PRF-FUT-PRS	Past = Participle = Present; Separate Root for Future	AABA
PRF-PST-FUT-PRS	Participle = Present = Future; Separate Root for Past	ABAA
PST-FUT-PRF-PRS	Past = Participle; Distinct Roots for Present and Future	ABAC
FUT-PST-PRF-PRS	Participle = Present = Future; Separate Root for Past	ABAA
FUT-PRF-PST-PRS	Participle = Present = Future; Separate Root for Past	AABA
PRF-FUT-PST-PRS	Participle = Present = Future; Separate Root for Past	AABA

Table 3.6: No matter what is the linear order, there are patterns that violate *ABA

.

The first column of the table showcases all the possibilities of a linear order for the four tense-stems. In front of each linear order, there is a pattern that would violate the *ABA generalization if that specific ordering is used. So no matter how we order the tenses linearly, we get *ABA violations. My focus for the rest of this chapter is to motivate a hierarchy, necessarily non-linear, where the semantic representation of the tense system inspires a hierarchy for the associated morphological forms. Once a specific connection between the semantic and the morphological tenses is made, the availability of some ABA patterns is due to the fact that the semantic relations between morphological tenses only induce a partial ordering.

[10] Germanic languages evidently violate this conclusion: *winken-gewunken-winkte* (German), and *vill-velat-ville* (Swedish). Andersson (2018) provides a diachronic explanation for these patterns in terms of Proto-Germanic conjugation classes.

3.2.3 Monotonic analysis of tense syncretism

A linear order of tense that includes future in addition to other three tenses (present, past, participle) cannot account for the attested patterns in terms of a *ABA analysis. Here I introduce a partial order of tense that takes care of all the attested patterns by only allowing monotonic mappings from this base hierarchy to an ordering of output forms.

Recall that in §2.1, I introduced monotonicity and its related concepts. Very briefly put, consider a function $f\colon A \to B$ between two sets A and B, where each set carries a partial order. The function f is monotonic if, whenever $x \leq y$, then $f(x) \leq f(y)$ (as mentioned in §2.1, I use *monotonic* as a shorthand for *monotonic increasing*).

Suppose that Present $\leq$ Participle $\leq$ Past, and Present $\leq$ Future, but Future is unordered with respect to Participle and Past. Then Future can be syncretic with any one of the three tenses to the exclusion of the others, allowing for a limited range of what appear to be ABA patterns. This is illustrated in (3.1) for the attested *ABA violations AABA and ABCB. The unattested ABAX patterns do not obey monotonicity, with the problematic cases indicated by the crossing branches in (3.1).

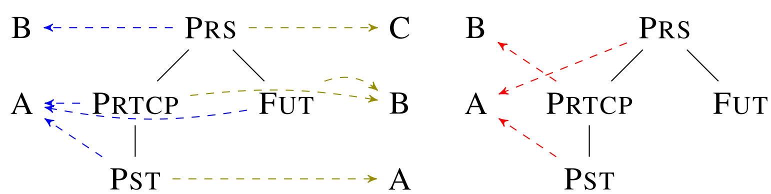


Figure 3.1: Monotonic (left) and non-monotonic (right) mappings in tense syncretism

This partial hierarchy allows for any kind of syncretism as long as the future is concerned (allowing all ABAX patterns with Future as A, B, or C). Moreover, this hierarchy might seem obvious given that the future and the future and the participle both are intuitively associated with the present. Fortunately, a more rigorous motivation for this particular hierarchy already exists in the form of Reichenbach's (1947) model of the semantics of tense, as I show next in §3.3. Reichenbach's account is widely used by language scientists and follows a logical structure. Hence it follows that its associated hierarchy of tense-stems is the most plausible way of configuring morphological forms. Even though I am not focusing on the future perfect in this research, further study of the future and its associated forms might tell us why the logical structure is configured the way it is.

3.3 Semantic motivation

The proposed hierarchy of temporal relations is independently motivated in terms of the tense system proposed by Reichenbach (1947). In this system, tense denotes a three-way relation

Table 3.7: A Tree Representation of Reichenbach's Tense System

between speech time (S), event time (E) and reference time (R). In Present, these values are equal (S=E=R). Gradual shifts from this default point in time builds a partial hierarchy of tense.

The hierarchy discussed in the next section is only applicable to languages in which the directional distinctions of time are reflected through temporal stems. The aim of the hierarchy is to delimit the range of the possible arrangements of tense stems to include only the attested patterns and all the attested patterns.

3.3.1 Reichenbach's tense theory

In Reichenbach's system, tense denotes a three-way relation between speech time (S), event time (E), and reference time (R). S denotes the moment the utterance is spoken, E is the temporal location of the event, and R is the point of time from which we are referring to the event. The position of R relative to S distinguishes the 3 tenses: 'past', 'present', or 'future': E is at R (R = E) and R is located relative to S: before, at or after S, respectively.

(10)

R	S		Past	$(R < S)$
	R,S		Present	$(R = S)$
	S	R	Future	$(R > S)$

The position of E with respect to R distinguishes 3 further possibilities: 'posterior' (viewing the situation E from an earlier point; looking forward), 'simple' (used for the coincidence of R and E) and 'anterior' (viewing the situation E from a later point; looking backward).

(11)

R	E		posterior	$(R < E)$
	R,E		simple	$(R = E)$
	E	R	anterior	$(R > E)$

The introduction of the notion of the reference time is considered Reichenbach's greatest contribution to the study of temporal relations. Its order relative to E yields the differentiation of the perfect, i.e., in the case of a perfect, E is located before R. In the past perfect R precedes S ($E < R$ and $R < S$). In the present perfect, R overlaps S ($E < R$ and $R = S$). Likewise, in the future perfect, both S and E precede R ($S < R$ and $E < R$).

All possible combinations involving a single time of speech (S) include three simple tenses (where $R = E$), five anterior tenses (where $E < R$), and five posterior tenses (where $R < E$).

Thus, the temporal system of a language could include up to 13 tenses. The actual number of tense realizations in each language depends on the number of grammaticalized combinations (Reichenbach, 1947, 77). In the tree representation, the branching is based on the relative order of the Event time and the Reference time. The event is anterior if it is behind us (back in time); it is posterior if it is ahead of us; and it is simple if the E and R are synchronized.

(12) *The logical distinctions of time ordered in terms of their inequality statements.*

Structure	Name	Traditional Name
E<R<S	Anterior past	Past perfect
E,R<S	Simple past	Simple past
R<E<S	Posterior past	———-
R<S,E	Posterior past	———-
R<S<E	Posterior past	———-
E<S,R	Anterior present	Present perfect
S,R,E	Simple present	Present
S,R<E	Posterior present	Simple future
S<E<R	Anterior future	Future perfect
S,E<R	Anterior future	Future perfect
E<S<R	Anterior future	Future perfect
S<R,E	Simple future	Simple future
S<R<E	Posterior future	———-

Comrie (1981) offers some modifications to this system that will prove useful in further motivating the connection of Reichenbachian tense semantics and the observed typology of tense syncretism. He argues that R is not involved in marking the absolute tenses, such as the simple past, present, and future in English. Rather these temporal relations are a result of the relation between E and S. In other words, absolute tenses locate an event with reference to the moment of speech (R and S are the same). R is only relevant when describing relative tenses (those indicating anteriority, simultaneity, etc.). Moreover, Comrie assumes that in the past perfect and the future perfect there are two binary relations, between E and R and between R and S, rather than one ternary relation among E, R, and S. I will use Reichenbach's system along with Comrie's comments to motivate a hierarchy able to accommodate our attested patterns of verbal relation, which are documented in the next section.

3.3.2 The problem of tense

Which relations are included in a hierarchy of tense? Clearly, absolute tenses (present, past, future) are part of this hierarchy, but present progressive, for instance, should not be included in it because it is an aspectual relation. The situation with perfects is different. Both Reichenbach and Comrie agree that perfect cannot be viewed as a canonical aspect since it tells us nothing about the internal temporal organization of the situation (Comrie, 1981). Perfect is like tense in that it locates an eventuality relative to some reference point. In the sentence *Paniz has eaten the cake*, there is an eventuality to the act of eating. This makes the present perfect very similar to the simple past. In Reichenbach's terms, the simple past expresses a temporal precedence between the Speech time and the Reference time, while the perfect expresses a temporal precedence between the Event time and the Reference time. Another point of difference between the present perfect and the simple past will be apparent once we add a past-oriented adverb to our example: **Paniz has eaten the cake yesterday*. It is unexpected for an anterior temporal relation to be incompatible with a past-oriented adverb (Klein (1992) refers to this situation as "the present participle puzzle").

More in support of positioning perfect among tense relations is the fact that perfect refers to a bundle of meanings that is maintained no matter what absolute tense it is associated with. Generally, three main readings are associated with perfects. These readings make different claims about the location of the underlying eventuality, although in some languages only a subset of them is allowed. For example, in Greek perfect participles are marked as perfective and as a result the universal reading is not possible (Pancheva, 2003, 278). In the following examples, the universal meaning asserts that an eventuality holds for an interval of time; in the experiential reading, the eventuality holds for a proper subset of an interval; and finally, in a resultative reading the result of the eventuality holds at the speech time (Pancheva, 2003).

(13) *Present Perfect:*
a. Paniz has lived in Tehran ever since. — *Universal Reading*
b. Paniz has been in Tehran before. — *Experiential Reading*
c. Paniz has arrived in Tehran. — *Resultative Reading*

(14) *Past Perfect:*
a. Since 2009, she had lived in Tehran. — *Universal Reading*
b. She had been in Tehran before that too. — *Experiential Reading*
c. She had just arrived in Tehran. — *Resultative Reading*

(15) *Future Perfect:*
a. Next month, Paniz will have lived in Tehran for 3 years. — *Universal Reading*
b. Paniz will have been in Tehran by the next fall. — *Experiential Reading*
c. Paniz will have arrived in Tehran by Friday. — *Resultative Reading*

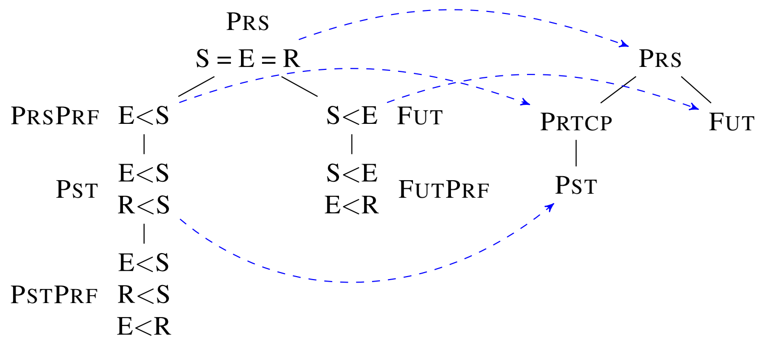
With these facts in order, I include perfects as part of the tense system.

(16)

R		S		Perfect	(R < S)
	R	S		Past	(R < S)
		R,S		Present	(R = S)
		S	R	Future	(R > S)

Once one considers only those tenses that are morphologically realized across languages, the order in (17) emerges clearly.

(17)



The only contentious issue is the locus of Participle, which could be associated with present perfect, past perfect, or future perfect. There are three reasons for identifying Participle with present perfect.

1. The present tense, according to Bybee, Perkins, and Pagliuca (1994, 152), refers to the default situation from which other tenses represent deviations. Along the same line, we can argue that the semantics of the past perfect and the future perfect follow from the semantics of the present perfect, combined with an account of the past tense and the future tense (Musan, 2001, 356).

2. The claim in (1) is verifiable by comparing the frequency rates of the perfects. The future perfect seems to be the least frequent among the perfects. In a corpus-based study of English perfect constructions, Bowie and Aarts (2012) show that the present perfect is the most frequently used type of perfect in English. They report a decrease in the usage of the present perfect by 0.8 – 0.9% (due to its shared meaning with the simple past), and in the past perfect by approximately 34% over the data drawn from the Diachronic Corpus of Present-day Spoken English (DCPSE). The change rate is calculated by comparing the earlier DCPSE subcorpus containing around 464,000 words from the London–Lund Corpus (LLC) dating from the late 1950s to the 1970s with the later subcorpus containing around 421,000 words from the British Component of the International Corpus of English (ICE-GB) collected in the early 1990s (Bowie and Aarts, 2012, 201).

3. The hierarchy of tense is an implicational hierarchy; if a language has a past perfect or a future perfect, it is very likely that it also has a present perfect (whereas the reverse does not necessarily hold). In this hierarchy, the present perfect has the least distance from the default point ($E = R = S$) with only one shift ($E < R, S$). The future perfect ($S < R < E$) and the past perfect ($E < R < S$) both undergo two shifts from the default. This results in the hierarchical ordering of the tenses. In an implicational system, this means that if a language has a past perfect or a future perfect, it is most likely that it also has a present perfect (but not the reverse).

These arguments, the semantics of the present tense, the frequency of the participle forms, and the implicational nature of the hierarchy, direct us to conclude that the locus of the participle on the morphological hierarchy should be associated with the node that represents the present perfect on the logical hierarchy. This association readily explains the problematic behavior of the future (§3.2.2), which cannot be accounted for with a total order (unless one assumes multiple positions for the future).

3.4 Conclusion

In this chapter, I have shown that Bobaljik's *ABA generalization holds for tense syncretism across a variety of languages, but only for three tenses: present, participle, and past. Future does give rise to apparent *ABA violations, but these are expected if one combines monotonicity Graf (2019a)—a more general notion of *ABA— with a partial order of tenses in the spirit of Reichenbach (1947).

In §3.2.2, I went over all the possible linear orderings of the four stems to show that no matter which linear order one chooses, there are attested patterns of syncretism that would violate *ABA. The problem with a linear hierarchy of tense is not simply that it does not adhere to the *ABA generalization. As I have argued, the main point is that the logical description of tense directs us towards a partial hierarchy. The hierarchy proposed in this chapter enjoys a major advantage compared to a linear order: its motivation is purely logical and based on the semantics of tense. Reichenbach's account is widely used by language scientists and follows a logical structure. Hence it follows that its associated hierarchy of tense-stems is the most natural way of configuring morphological forms.

My proposed partial hierarchy of tense is like a two-branched tree, with one branch going to the past and one to the future. This structure allows for any kind of syncretism that is concerned with the future tense. This might not seem desirable as it is too permissive, but it is the kind of structure that is directly extracted from the logical system of tenses. Additionally a more in-depth study of the future tense, and specifically future perfect, may eventually lead us to findings that justify the two separate branches. It is important to keep in mind that placing future on a separate branch of the tense hierarchy is not an empirically vacuous claim. It makes specific empirical predictions about what kind of syncretisms are possible, and these predictions can be verified by careful analysis of the typological data. Specifically, according to the data and analysis presented here, we should be able to find ABBA (past = future; participle = present), and ABCA (past = future; Distinct roots for participle and present) patterns across languages, but they are missing from the attested patterns in the current literature.

Chapter 4

Resolved Agreement

The mission of the current chapter is to extend the monotonicity approach introduced in Chapter 2 to resolved agreement. I specifically focus on gender resolution, which operates to resolve clashes of values or to show shared values in gendered paradigms. Resolved agreement in gender shows a range of diverse patterns where the resolved form can be determined by either one or all conjuncts. For example, in French the coordination of a masculine and a feminine resolves in a masculine predicate. Here the resolved form is solely determined by the masculine conjunct. In Slovenian, on the other hand, the coordination of two neuter conjuncts resolves in masculine agreement. Here the two conjuncts share the same value and the form of the predicate is determined by considering both of the conjuncts.

I have explored a wide range of languages in order to find those where resolution is at work. Eventually, I collected a representative sample of more than 20 languages to understand why only a few of the logically conceivable patterns of resolved agreement are attested. The number of logical possibilities of resolved agreement for languages with 2 gender values is $2^4 = 16$. Yet only two patterns are attested. The same happens in 3-gender languages: out of $3^9 = 19,683$ possibilities, only six patterns are attested. Starting from an underlying hierarchy of $m < n < f$, I construct a pointwise algebra to represent various gender combinations. Combining abstract algebra and the mathematical notion of monotonicity helps us understand the nature of the restricted set of attested patterns. This suggests that there might be external ordering principles for gender, similar to what we saw with tense in Chapter 3.

4.1 Introduction

Hockett (1958, 231) defines genders as “classes of nouns reflected in the behavior of associated words”. Agreement, in this case, is a relationship between the controller (the element determining agreement, e.g., subject noun phrase) and the target (the element whose form is determined by agreement) (Corbett, 2006, 4). Consider the French example in (18) where both the determiner and the adjective agree with the nouns *jardin* and *cour* in gender and number:

(18) a. un grand jardin
a.MSC big.MSC garden.MSC

b. une grande cour
a.FEM big.FEM yard.FEM

Gender agreement in French seems straightforward: specify the gender of the NP and agree with it. The articles *un*, *une* and the adjectives *grand* and *grande* all agree in their morphosyntactic properties. If changed to the plural, the agreement still remains identical:

(19) a. grand-s jardin-s
big.MAC-PL garden.MSC-PL

b. grande-s cour-s
big.FEM-PL yard.FEM-PL

Conjoined noun phrases, however, make agreement a central problem in languages with grammatical gender. Aside from languages like Yimas, where conjoining noun phrases are prohibited Corbett (1991, 264), languages use two agreement strategies to determine the realization of gender in the plural: agreement with one conjunct and gender resolution rules. In conjoining the two nouns in the previous examples, the predicate needs to use resolution rules in French. This means that the predicate shows masculine agreement.

(20) le jardin et la cour sont grands
the.MSC garden.MSC and the.FEM yard.FEM are big.MSC.PL

When the resolutions rules do not apply, agreement is normally with one of the conjuncts. Agreement with one conjunct usually fixes on the closest conjunct to the target. In Swahili, for instance, the verb agrees with the nearest conjunct: In (21), the agreement pattern is 3-7-7, where the verb agrees with *ki-ti* 'chair', a 7/8 noun, in gender. Once we reverse the order of the two nouns, the agreement pattern changes direction as well (7-3-3).

(21) m-guu wa meza na ki-ti ki-mevunjika
3-leg of table and 7-chair 7-be.broken
'The leg of the table and the chair are broken' Swahili

(22) ki-ti na m-guu wa meza u-mevunjika
7-chair and 3-leg of table 3-be.broken
'The chair and the leg of the table are broken.' (Bokamba, 1985, 45)

This phenomenon, also known as partial agreement, is not relevant to the current study and I will not focus on it any further (Corbett, 1991, 264-7). In what follows, I start with a short introduction to resolved agreement and the features requiring it (§4.2). Then I proceed to §4.3 where I explain the nature of the gender hierarchy and how to construct it. This hierarchy is going to be used to account for the typologically attested patterns of gender resolution that are gathered in §4.4. These include 3 types of patterns: syntactic resolution (§4.4.1), semantic resolution (§4.4.3), and the mixed-type resolution (§4.4.2). I discuss the types of hierarchies used in each section and conclude the chapter in §5.6.

4.2 Resolved Agreement

Resolved agreement is a term used to describe the predicate agreement with a subject made up of coordinated elements. The rules that determine the forms to be used are called resolution rules. The morphosyntactic features that require resolution are person, number and gender.

The resolution rules for person and number are semantically transparent. For person, resolution rules are ordered based on the linguistic person hierarchy where the first person precedes the second and the second person takes precedence over the third (Zwicky 1977, 718; Corbett 1991, 262).

(23) *Person Resolution Rules:*
1. First person agreement is used if the conjuncts include a first person;
2. Second person agreement is used if the conjuncts include a second person;
3. Third person agreement is used by default.

As for number resolution, the rules depend on the number of grammatical numbers in individual languages. For a typical language, conjoined noun phrases require the plural. If the language also has a dual number, then another rule precedes the general plural requirement: dual agreement is used if there are two singular conjuncts. The number resolution rules for such a language are given in Corbett (1983, 177); Corbett (1991, 263).

(24) *Number Resolution Rules:*
1. If there are two singular conjuncts, then dual agreement forms are used;
2. In all other cases with at least one non-plural conjunct, plural agreement forms are used.

Gender resolution rules show greater diversity. This is mainly because they do not always have a unified semantic justification (Corbett, 1991, 264). In French for instance, if two nominal heads, one feminine and one masculine, are conjoined, the resolved form is always masculine. Thus the resolution rules in French favor masculine agreement as the default gender. This is different from Icelandic or inanimate coordination in Romanian where neuter and feminine are favored, respectively.

(25) [le garçon et la fille] sont compétents
[the boy.M and the girl.F] are competent.M.PL
'The boy and the girl are competent.' French

(26) [frægð-∅ og fram-i] eru tvíeggj-uð
[fame.F.SG and success.M.SG] are double.edged-N.PL
'Fame and success are double-edged.' Icelandic (Friðjónsson, 1991, 90)

(27) [ușa și peretele] ele...
[door.F.the and wall.M.the] theyF.PL...
'The door and the wall, they...' Romanian (Corbett, 1991, 288)

Not all languages with gender require gender resolution rules. German and Russian both have three genders that only need agreement in the singular. Agreement in the plural is not problematic since there is only one form for all three genders.

SG	**PL**
MSC	
FEM	NEUT
NEUT	

Table 4.1: Target genders in German and Russian

Then there are languages like Luganda and Temne that ban conjunction between human and non-human noun phrases. The preferred construction in such cases is the comitative. In Ojibwa, the same restriction applies to animate and inanimate coordination (Corbett, 1991, 264-65). I conclude that forms of gender resolution are diverse, not always semantically transparent, and are banned in some languages or under certain conditions.

Just like tense syncretism, resolved gender stands out for how small the number of realized systems is relative to how many logically conceivable options there are. To fully appreciate this point, let us take a moment to look at the combinatorics of resolved gender. Given k possible genders, there are k ways for any two genders and k^{k^2} resolution systems. Assuming that the order of elements in a coordination does not matter, the number of resolution systems equals $k^{k(k+1)/2}$. This is explained below using *triangular numbers*.

Assume that (a + b) is our coordination and the number of gender values in different languages are the exponents. In each line, the binomial expansion of each expression is given. We then abstract out of the mathematical details and replace them by a dot (•).

$(a+b)^0$			1				•
$(a+b)^1$		a		b			• •
$(a+b)^2$	a^2		2ab		b^2		• • •
$(a+b)^3$	a^3	$3a^2b$		$3ab^2$		b^3	• • • •

The number of dots in each triangular pattern is its *Triangular Number*. The first triangle, a gender-less system (g=0) has just one dot. The second triangle (g=1) has another row with 2 extra dots, making 1+2=3 dots. The third triangle (g=2) has another row with 3 extra dots, making 1+2+3=6 dots. The fourth (g=3) has 1+2+3+4=10 dots.

The rule for calculating any triangular number is as follows. First, we rearrange the dots as below:

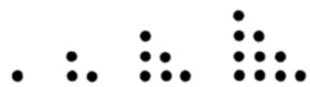


Figure 4.1: Triangular numbers are the number of dots in each triangular pattern.

Then double the number of dots, and form them into a rectangle which has the same number of rows but has one extra column (to make this clear the two triangles are shown in green and red).

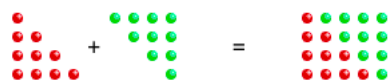


Figure 4.2: Doubling the number of dots in each triangular pattern to form a rectangle.

Now it is easy to see that the number of dots in a rectangle is $n(n+1)$ and the number of dots in a triangle is half that, i.e., $n(n+1)/2$.

Despite the remarkable diversity in grammatical gender systems, the attested gender resolution patterns constitute but a few of the large number of possibilities. For languages with 2 genders, the above formula yields $2^{2(2+1)/2} = 2^{6/2} = 2^3 = 8$ possibilities. Assume a language with MSC and FEM genders. With these two genders, there are 6 possible resolution rules. (In (28) and (29), Cs stand for conjuncts and the subscript show their gender.)

(28) *Possible resolution rules in a 2-gender system*

(1) $C_f + C_m \rightarrow C_f$	(2) $C_f + C_m \rightarrow C_m$
(3) $C_f + C_f \rightarrow C_f$	(4) $C_f + C_f \rightarrow C_m$
(5) $C_m + C_m \rightarrow C_m$	(6) $C_m + C_m \rightarrow C_f$

There are 8 ways for grouping these resolution rules for any language. Yet only two patterns (Lang 1 and Lang 5) are attested in our sample of seven 2-gender languages (French, Spanish, Latvian, Hindi, Panjubi, Modern Hebrew and Romanian).

(29) *Possible languages for a 2-gender system using the resolutions in (28)*

Lang 1: (1), (3), (5)	Lang 2: (1), (3), (6)
Lang 3: (1), (4), (5)	Lang 4: (1), (4), (6)
Lang 5: (2), (3), (5)	Lang 6: (2), (3), (6)
Lang 7: (2), (4), (5)	Lang 8: (2), (4), (6)

The same happens in 3-gender languages: out of $3^{3(3+1)/2} = 3^{6/2} = 3^6$ = 729 possibilities only 6 are realized. The space of logical possibilities quickly becomes quite large, as more and more genders are added: $8, 729, 1,048,576$ (million), $30,517,578,125$ (billion), $21,936,950,640,377,856$ (quadrillion), etc.

In the present chapter, I show that the restricted set of attested patterns can be defined by their monotonic nature. As explained previously in Chapter 2, Graf (2019a) proposes monotonicity as a formal universal of morphosyntax. The account comes with two requirements. First is that morphosyntactic domain should have a base hierarchy (e.g. person: $1 < 2 < 3$), and then it should follow that the mappings from a hierarchy to surface forms must be monotonic.

The gender hierarchy is directly extracted from the organization of the typological data. I explain the process of building up such a hierarchy in the next section (§4.3). The crucial finding is that even though masculine and feminine genders should be ordered with respect to each other to reflect the ordering of data in individual languages, the general gender hierarchy does not favor one gender over another. In other words in a 3-gender system, both $m < n < f$ and $f < n < m$ can keep the system monotonic. One way to look at it is to see gender assignment along a path with two end nodes (masculine and feminine nodes). You can equally use the two nodes to assign gender in a given language. Meanwhile, neuter, which means 'neither' in Latin, is negatively defined as neither feminine nor masculine. Those nouns not selected by either end of the hierarchy will be assigned to the middle gender, the neuter.

4.3 An Algebra for Gender Resolution

By definition, if A is some algebraic structure, the set of all functions X to the domain of A can be turned into an algebraic structure of the same type in an analogous way. Let us assume an underlying hierarchy of $f < n < m$ and construct a pointwise algebra to represent various gender combinations. At the top of the algebra $\langle m,m\rangle$ stands for the combination of two masculine genders. At the bottom, $\langle f,f\rangle$ represents the coordination of two feminine noun phrases. All other combinations are ordered between these two nodes. The two edges of the structure expand by combining MASC with NEUT which is the second in the hierarchy. The combination in the center of the next step, $\langle n,n\rangle$, inherits the NEUT gender from the the two nodes above it. Then the FEM is introduced to the hierarchy and it combines with the MASC to form the two symmetric nodes in the middle of the structure ($\langle m, f \rangle$ and $\langle f, m \rangle$). Finally there is the combination of the NEUT and FEM genders ($\langle n, f \rangle$ and $\langle f, n \rangle$) right before the final $\langle f, f \rangle$ node.

(30) *The algebra of gender combinations*

$$\begin{tikzcd}
& & \{m,m\} \arrow[dl, dash] \arrow[dr, dash] & & & & \mathrm{MASC} \arrow[dd, dash] \\
& \{m,n\} \arrow[dl, dash] \arrow[dr, dash] & & \{n,m\} \arrow[dl, dash] \arrow[dr, dash] & & & \\
\{m,f\} \arrow[dr, dash] & & \{n,n\} \arrow[dl, dash] \arrow[dr, dash] & & \{f,m\} \arrow[dl, dash] & & \mathrm{NEUT} \arrow[dd, dash] \\
& \{n,f\} \arrow[dr, dash] & & \{f,n\} \arrow[dl, dash] & & & \\
& & \{f,f\} & & & & \mathrm{FEM}
\end{tikzcd}$$

Note that the combination of genders is represented as sets instead of tuples because in resolved agreement the order of the coordinated elements does not matter (i.e., {m,n} = {n,m}). Thus we remove all the symmetrically repeated sets from the previous algebra to arrive at the simplified hierarchy in (31). Elements of this algebra are then mapped into a hierarchy of plural genders, and these mappings, as we will see in the next section, are indeed monotonic for all the languages in our data set.

(31) *The simplified algebra of gender combinations*

$$\begin{tikzcd}
& \{m,m\} \arrow[d, dash] & & \mathrm{MASC} \arrow[dd, dash] \\
& \{m,n\} \arrow[dl, dash] \arrow[dr, dash] & & \\
\{m,f\} \arrow[dr, dash] & & \{n,n\} \arrow[dl, dash] & \mathrm{NEUT} \arrow[dd, dash] \\
& \{f,n\} \arrow[d, dash] & & \\
& \{f,f\} & & \mathrm{FEM}
\end{tikzcd}$$

In most languages, the plural genders use the same hierarchy from which the pointwise algebra is constructed. However, there are languages that instead use a condensed hierarchy in this case. Most of these languages follow the semantic principle in gender resolution, based on which the meaning of the conjoined elements determines the resolution (Corbett, 1991, 269-278). The condensed hierarchy is usually polarized between RATIONAL > IRRATIONAL (as in Dravidian languages) or HUMAN > NON-HUMAN (as in Bantu languages). We will explore examples from both language families in this chapter.

All gender systems have some semantic basis or at least origin, though very few are completely motivated synchronically. Corbett (1991) discusses this at length. Admittedly, gender systems are not uniform in the way person systems mostly are. The surprising fact, then, is not that gender hierarchies can differ across languages, but the overwhelming uniformity of hierarchies across the available data sample, whose varieties we see in the next section.

4.4 Attested Patterns

Gender assignment across languages follow two general strategies (Aksenov 1984; Corbett 1991; Comrie 1999). First is formal assignment based on morphophonological properties. This kind of assignment is uninterpretable; it satisfies grammaticality conditions, but it does not have any semantic contribution. The second kind of assignment is semantic. Not only does it satisfy grammaticality conditions, it also denotes relevant and salient conceptual properties, e.g., humanness, animacy, sex, etc. Most languages use a combination of the two types of gender assignment.

Similarly, gender resolution rules are of different types. In Corbett (2003) it is claimed that the type of gender resolution system in a language is related to its gender assignment system:

> Languages with strict semantic assignment systems (like Godoberi) have semantic resolution systems, as do those with predominantly semantic systems (like Archi). Languages with formal assignment systems may have semantic resolution (Luganda), mixed (Latin) or syntactic (=formal) resolution (as in the case of French).

Gender resolution by the semantic principle is based on the meaning of the conjoined elements, even if this implies ignoring their syntactic gender. In Bantu languages, all humans belong to 1/2 gender but not all 1/2 gendered nouns are humans (1/2 is used to indicate singular agreement as belonging to class 1 and plural agreement belonging to class 2). For gender resolution, however, the important thing is whether a noun is human or not, regardless of its gender. If the conjuncts in a coordination refer to human entities then the resolved form is the class 2 marker. If none of the conjuncts denote a human, then the class 8 form is used. In most cases, conjoining nouns denoting human and non-human results in an unnatural construction where the preferred form is the comitative construction (Corbett, 1991).

Syntactic resolution, on the other hand, is based on the grammatical gender of the nouns involved rather than their meanings. French has two genders, masculine and feminine. If in a coordination the conjuncts are of the same gender, then that gender will be used as the resolved form. If one conjunct is masculine and another is feminine, then a masculine form is used. These rules are not sensitive to the meaning of the conjuncts and will be applied to all the nouns in each class.

For languages with a mixed type, the hierarchy might be twisted in specific ways. For example, semantic and syntactic principles of gender resolution coexist in Latin. In a coordination, conjuncts of the same syntactic gender take agreeing forms of that gender: if all feminine, then feminine;

and if all masculine, then masculine. This part of gender resolution in Latin is syntactic. But if conjuncts are of different genders, then the resolved form depends on whether nouns refer to human or non-human entities. If the conjuncts are human, the masculine is used; and if they are not human, the neuter is used.

The following section shows our treatment of the data for a number of languages in each category. The cross-linguistic data used in this chapter is also available at https://github.com/somoradi/somoradi/tree/master/ThesisAppendix.

4.4.1 Syntactic Resolution

French Let us start with the simplest gender system we can consider. In French there are two genders, feminine and masculine. If in a coordination the conjuncts are of the same gender, then that gender will be used as the resolved form.

(32) a. [La fille.F et sa soeur.F] sont compétentes.F.PL / *compétents.M.PL
b. [Le garçon.M et son frére.M] sont compétents.M.PL / *compétentes.F.PL

However, if one conjunct is masculine and another is feminine, then a masculine form is used.

(33) a. [Le garçon.M et la fille.F] sont compétents.M.PL / *compétentes.F.PL
b. [Un savoir.M et une adresse.F] merveilleux.M.PL / *merveilleuses.F.PL

Languages like French are quite common, e.g., Spanish, Latvian, Hindi, Italian, Panjabi, and Modern Hebrew (see Corbett (1991, 261-306); Corbett (2003)). The resolution rules for these languages look like the rules given in §4.4.1

(34) Resolution Rules in French
a. Feminine is used if all conjuncts are feminine (F)
b. Otherwise the masculine is used. (M)

These rules apply with the same effect to human/non-human or animate/inanimate nouns. Hence the system is motivated by the syntactic principles of gender resolution.

Table 4.2: Gender values and resolution in French

SG	PL
MSC	MSC
FEM	FEM

	MSC	FEM
MSC	M	M
FEM	M	F

We start by building a hierarchical algebraic construction based on an underlying hierarchy of gender. Assuming $f < m$, we construct a pointwise algebra to represent the possible gender combinations. At the top of the algebra {m,m} stands for the combination of two masculine genders. At the bottom, {f,f} represents the coordination of two feminine noun phrases. All other combinations are ordered between these two nodes ({m,f} & {f,m}). These two sets are the same, so we remove one of them to arrive at a more simplified hierarchy.

(35) *Gender hierarchy in French*

$$
\begin{tikzcd}[column sep=small]
 & \{m,m\} \arrow[dl, dash] \arrow[dr, dash] & \\
\{m,f\} \arrow[dr, dash] & & \{f,m\} \arrow[dl, dash] \\
 & \{f,f\} &
\end{tikzcd}
\qquad
\begin{tikzcd}
\{m,m\} \arrow[d, dash] \\
\{m,f\} \arrow[d, dash] \\
\{f,f\}
\end{tikzcd}
\qquad
\begin{tikzcd}
\textsc{msc} \arrow[dd, dash] \\
 \\
\textsc{fem}
\end{tikzcd}
$$

Elements of this algebra are then mapped into a hierarchy of plural genders. As we can see these mappings are all monotonic. In languages with a gender structure like French, it does not matter which gender is higher in the hierarchy. If you flip the structure in (35) you get the same kinds of mappings but in the reverse order.

(36) *Monotonic gender mappings in French*

$$
\begin{tikzcd}
\langle m,m\rangle \arrow[d, dash] \arrow[r, dashed] & \textsc{msc} \arrow[dd, dash] \\
\langle m,f\rangle \arrow[d, dash] \arrow[ur, dashed] & \\
\langle f,f\rangle \arrow[r, dashed] & \textsc{fem}
\end{tikzcd}
$$

Slovenian Another language with a dominantly syntactic resolution system is Slovenian. Slovenian has three numbers and three genders. The predicate agreement forms are given in 4.3. In this table, *bil* is the past active participle of the verb 'be' Corbett (1991, 280). The number resolution rules determine the use of dual and plural. The dual forms will result only if the two conjoined noun phrases are singular. The gender resolution works the same for both dual and plural conjunctions. The gender system in Serbo-Croatian is similar, except that there is no dual there.

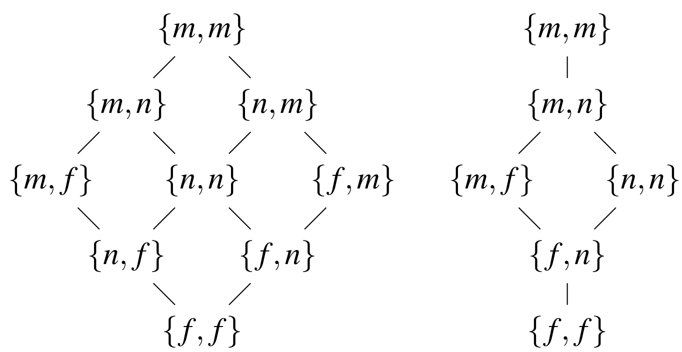
<table>
<tr><th></th><th>SG</th><th>DL</th><th>PL</th><th></th></tr>
<tr><td>MSC</td><td>∅</td><td>a</td><td>i</td><td>MSC</td></tr>
<tr><td>FEM</td><td>a</td><td rowspan="2">i</td><td>e</td><td>FEM</td></tr>
<tr><td>NEUT</td><td>o</td><td>a</td><td>NEUT</td></tr>
</table>

Table 4.3: Genders in Slovenian

A masculine noun conjoined with a masculine will resolve in masculine. The same way, a feminine noun conjoined with a feminine will resolve in feminine. But a masculine noun conjoined with a feminine or with a neuter resolves in a masculine predicate. If a feminine and a neuter are conjoined, you will still find the masculine agreement on the predicate.

In order to explore the hierarchical structure of Slovenian, once again we start from an underlying hierarchy of $f < n < m$ to construct a pointwise algebra and represent the gender combinations. At the top of the algebra {m,m} stands for the combination of two masculine genders. At the bottom, {f,f} represents the coordination of two feminine noun phrases. All other combinations are ordered between these two nodes. In the simplified structure, all the repeated sets all removed.

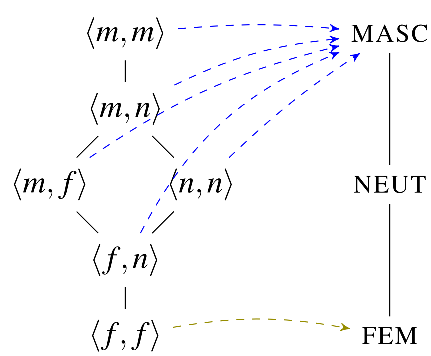
(37) *The gender hierarchy in Slovenian*



Based on the resolution rules in Slovenian, all the mappings of resolved agreement in this language are monotonic.

(38) *Resolution Rules in Slovenian*
a. Feminine is used if all conjuncts are feminine;
b. Otherwise, the masculine is used.

(39) *Monotonic mappings in Slovenian*



In a sense, the resolved agreement in Slovenian (and similar languages like Serbo-Croatian) favors the masculine. Feminine is only used if all conjuncts are feminine, and the neuter is not used at all. However, this does not mean that the masculine value should strictly be higher in the hierarchy. Interestingly, we will have the same monotonic mappings if we flip over the structure along with the hierarchy. As long as the neuter is in the middle, all the mappings are indeed monotonic.

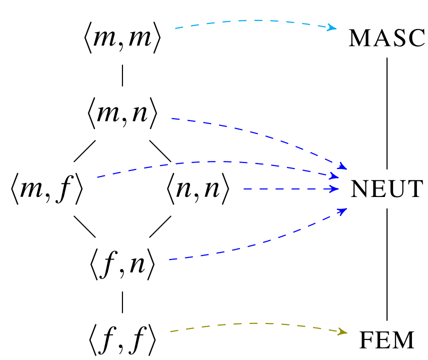
Icelandic We saw that resolution rules in Slovenian and Serbo-Croatian discriminate against the neuter in dual and plural numbers. In Icelandic, however, it is the favored form of resolution.

Icelandic has three genders: masculine, feminine, and neuter. When two conjuncts share the same gender value, the resolved form has the same gender in the plural. In resolution with all other conjoined combinations, neuter plural is used (Friðjónsson, 1991, 101).

(40) *Resolution Rules in Icelandic*
a. Masculine is used if all conjuncts are masculine;
b. Feminine is used if all conjuncts are feminine;
c. Otherwise, the neuter is used.

Icelandic comes with the same set of gender values as Slovenian. Thus we should see if the resolved agreement mappings in this language are monotonic over the same hierarchy of gender. A hierarchy where neuter comes in between masculine and feminine guarantees monotonic mappings that include all the resolved agreements in Icelandic.

(41) *Monotonic mappings in Icelandic*



As was the case with Slovenian, the order of masculine and feminine does not matter in this hierarchy. The important fact is to keep neuter in between those two values.

4.4.2 Mixed-Type Resolutions

Latin Latin shows a mixture of semantic and syntactic principles. There are three genders in this language: masculine, feminine and neuter. Conjuncts of the same gender resolve in a form from the same gender. This is purely syntactic resolution.

Non-human	MSC	FEM	NEUT
MSC	M	N	N
FEM	N	F	N
NEUT	N	N	N

Table 4.4: Non-human resolution rules

Human	MSC	FEM	NEUT
MSC	M	M	M
FEM	M	F	M
NEUT	M	M	M

Table 4.5: Human resolution Rules

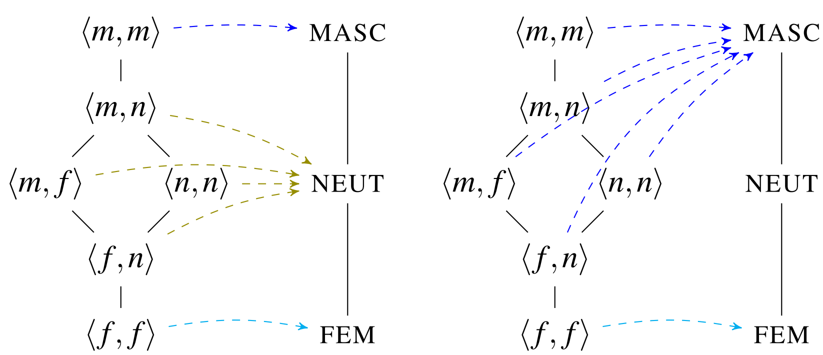
If conjuncts are of different genders, though, the criterion is purely semantic. Here the resolved form to be used depends on whether the nouns denote persons or not Corbett (1991, 287).

(42) *Resolution Rules in Latin*
a. Masculine is used if all conjuncts are masculine;
b. Feminine is used if all conjuncts are feminine;
c. Masculine is used if all conjuncts are human;
d. Otherwise, neuter is used.

The rules are ordered in this way because the masculine and the feminine genders are not semantically restricted to humans. This means that a human feminine in conjunction with a human masculine resolve in masculine rather than the default neuter.

In order to show these mappings, we divide the rules into two sets of human and non-human rules. Within each sub-system, all the mappings are monotonic.

(43) *Monotonic mappings in Latin non-human (left) and human (right)*



This is rather interesting. Even though Latin uses two patterns, they both operate over the same gender hierarchy. In Chapter 5, we will see the same strategy at work in most languages. Even though they are using different patterns of syncretism, all those patterns produce monotonic mappings over a single hierarchy that the languages chooses.

Romanian Here we witness a similar mixed system to that of Latin. The interesting difference is that Romanian is argued to have a third gender in addition to the two masculine and feminine values. This third gender is sometimes referred to as ambigender or neuter. When singular, it is the same as masculine; and when plural, it is the same as feminine. Since in a coordination environment the noun already has one of the two gender values, this third gender is not a problem for our account. However, resolution rules in Romanian are different for animate and inanimate nouns. Thus, even though the rules are generally referred to gender (to meet the syntactic criterion), they are different based on animacy (a semantic criterion).

(44) a. For animates:
   i. Feminine is used if all conjuncts denote feminine animate
   ii. Otherwise, the masculine is used.
 b. For inanimates:
   i. Masculine is used if all conjuncts are masculine
   ii. Otherwise, the feminine is used.

	MSC	**FEM**
MSC	M	M
FEM	M	F

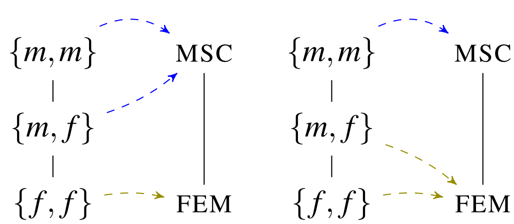
Table 4.6: Animate Rules, Romanian

	MSC	**FEM**
MSC	M	F
FEM	F	F

Table 4.7: Inanimate Rules, Romanian

Although Romanian requires two semantically distinct sets of resolution rules, the relationships are similar to the ones in French. All the mappings are monotonic over a hierarchy that posits one gender over another.

(45) *Animate and inanimate mappings in Romanian*



But what happens when we want to combine an animate noun with an inanimate noun. We collapse the former rules into the following. In the table I have used MSC-A to refer to masculine animate and MSC-I for masculine inanimate. The same distinction applies to the feminine values.

(46) *General rules of resolution in Romanian*
 a. If one conjunct denotes a male animate then masculine is used.
 b. If all conjuncts are masculine, then masculine is used.
 c. Otherwise, the feminine is used.

In order to build a structure that includes all the syntactic and semantic requirements of this complex system, we have to divide both masculine and feminine into animate and inanimate

	MSC-A	MSC-I	FEM-A	FEM-I
MSC-A	M	M	M	M
MSC-I	M	M	F	F
FEM-A	M	F	F	F
FEM-I	M	F	F	F

Table 4.8: General resolution patterns in Romanian

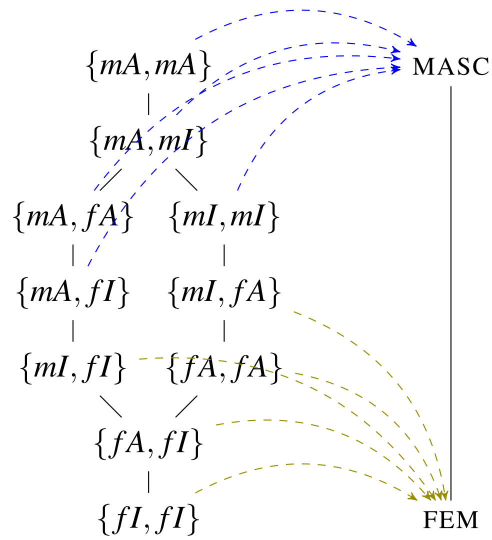
values. Let's take our former $f < m$ hierarchy and divide each value by the animacy principle. Cross-linguistically animates rank higher than inanimates and that is why we posit MSC-A over MSC-I and FEM-A over FEM-I.

(47) *The structure of the mixed gender hierarchy in Romanian*

$$\begin{array}{c}
\{mA,mA\} \\
\diagup \quad \diagdown \\
\{mA,mI\} \quad \{mI,mA\} \\
\diagup \quad \diagdown \quad \diagup \quad \diagdown \\
\{mA,fA\} \quad \{mI,mI\} \quad \{fA,mA\} \\
\diagup \quad \diagdown \quad \diagup \quad \diagdown \quad \diagup \quad \diagdown \\
\{mA,fI\} \quad \{mI,fA\} \quad \{fA,mI\} \quad \{fI,mA\} \\
\diagdown \quad \diagup \qquad \diagup \quad \diagdown \quad \diagup \\
\{mI,fI\} \quad \{fA,fA\} \quad \{fI,mI\} \\
\diagdown \quad \diagup \quad \diagdown \quad \diagup \\
\{fA,fI\} \quad \{fI,fA\} \\
\diagdown \quad \diagup \\
\{fI,fI\}
\end{array}
\qquad\qquad
\begin{array}{c}
\{mA,mA\} \\
| \\
\{mA,mI\} \\
\diagup \quad \diagdown \\
\{mA,fA\} \quad \{mI,mI\} \\
| \qquad\qquad | \\
\{mA,fI\} \quad \{mI,fA\} \\
| \qquad\qquad | \\
\{mI,fI\} \quad \{fA,fA\} \\
\diagdown \quad \diagup \\
\{fA,fI\} \\
| \\
\{fI,fI\}
\end{array}$$

After removing all the symmetrically repeated combinations, we arrive at a simpler structure that follows the same hierarchy of animate-gender principles. As (4.4.2) shows, all the mappings from this structure to the original hierarchy are monotonic.

(48) *Monotonic mappings in Romanian*



Polish Polish has three genders: masculine, feminine, and neuter. The masculine gender has two values: personal and non-personal. The form of these two are the same in the singular. In the plural, though, the masculine personal marking is different from the masculine non-personal. The last one shares the same form with the feminine and the neuter. The possibilities of predicate agreement are given in Table 4.9.

		SG	PL
MSC	personal	Ø/y/i	i/y
	non-personal		y/e
FEM		a	
NEUT		o/e	

Table 4.9: Genders in Polish

In the singular, Polish shows a three-way agreement involving masculine, feminine, and neuter. In the plural the division is into masculine personal and the remainder, which take the masculine non-personal form. The masculine impersonal does not exactly match the semantic criterion of male human, but it is tightly related to that category. If in a coordination structure one of the conjuncts is a masculine personal, then that form is used as the resolved form. If none of the conjuncts is headed by a masculine personal, then the non-masculine personal form is used.

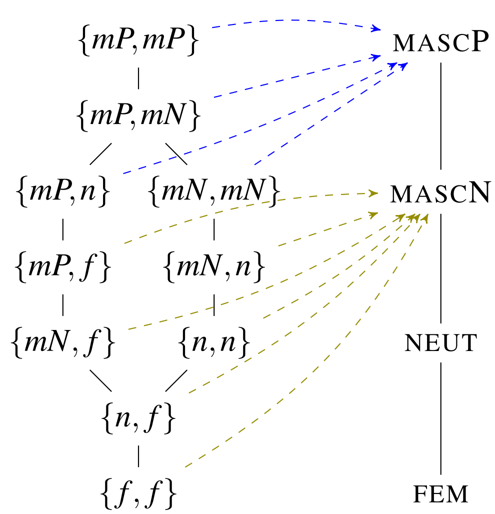
(49) *Gender Resolution Rules in Polish*
a. Masculine personal is used if at least one conjunct is masculine personal (M_p).
b. Otherwise, the masculine non-personal is used (M_n).

The resolution rules in Polish refer both to gender and to semantic criteria, resulting in a mixed-type resolution system (Corbett, 1991, 287).

	MSC-P	**MSC-N**	**FEM**	**NEUT**
MSC-P	M_p	M_p	M_p	M_p
MSC-N	M_p	M_n	M_n	M_n
FEM	M_p	M_n	M_n	M_n
NEUT	M_p	M_n	M_n	M_n

Table 4.10: Gender Resolution in Polish

(50) *Monotonic mappings in Polish*



4.4.3 Semantic Resolution

As discussed before, gender resolution by semantic principles is mainly based on the meaning of the head nouns involved in the construction, even if this requires overriding their gender values. This is a central property that affects the interpretation of gender hierarchies in this work. Let us see how this works out in three typologically different languages.

Tamil Dravidian languages are arch examples of this type of resolution. Tamil has three genders: masculine (for nouns denoting male rationals), feminine (for nouns denoting female rationals) and neuter (for non-rationals). The resolved forms, however, result in two forms only: rational and neuter. The resolution rules in Telugu, another Dravidian language, is the same as Tamil. This happens despite the fact that in Telugu, feminine and neuter are not distinguished in the singular.

If, in a coordination structure, all conjuncts denote rationals, the rational form is used.

SG	PL
MSC	RATIONAL
FEM	
NEUT	NEUT

Table 4.11: Target genders in Tamil

If all conjuncts denote neuters, the neuter form should be used.

The combination of a rational (feminine or masculine) with a neuter is generally avoided. But if ever allowed, the rational form is used.

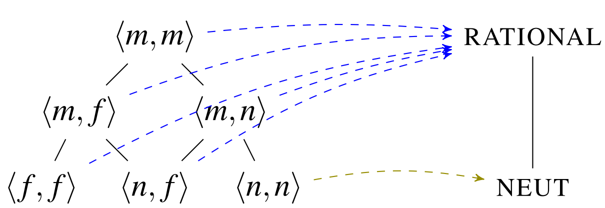
(51) *Resolution Rules in Tamil*
a. Rational is used if all conjuncts are rational;
b. Neuter is used if all conjuncts are non-rational;
c. Otherwise, rational is used, although an alternative construction is preferred.

	MSC	**FEM**	**NEUT**
MSC	R	R	R
FEM	R	R	R
NEUT	R	R	N

Table 4.12: Gender Resolution in Tamil

Over a hierarchy that places rational (including masculine and feminine) over neuter, all the mappings from controller genders to target genders are monotonic.

(52) *Monotonic mappings in Tamil*



The resolution rules in Tamil are not based on formal gender values but rather follow the two semantic values, RATIONAL and NEUTER. This means that there are only two classes of nouns in the plural. Hence we can reconstruct a hierarchy that only includes those two values in a linear order. The mappings over this hierarchy are all still monotonic.

(53) *Monotonic semantic mappings in Tamil*

$$\begin{tikzcd}
\langle r,r\rangle \arrow[r, dashed] \arrow[d, dash] & \text{RATIONAL} \arrow[dd, dash] \\
\langle r,n\rangle \arrow[ur, dashed] \arrow[d, dash] & \\
\langle n,n\rangle \arrow[r, dashed] & \text{NEUT}
\end{tikzcd}$$

Archi Archi is a North-East Caucasian language. The correlation between controller and target genders in Archi are as summarized in (54).

(54) *Archi gender system*
I. male humans: God and other spritual beings
II. females
III. most animals + some inanimates
IV. some animals + most inanimates

	SG	**PL**	
I. MSC	w	b/ib	rational
II. FEM	d		
III. ANIMATE	b	ib	irrational
IV. INANIMATE	t		

Table 4.13: Genders in Archi

Even though there are four classes of gender values, Archi only uses two genders for the resolved forms. Bellow, I use *R* to refer to the rational gender and *I* is used for the irrational gender value (Table 4.14).

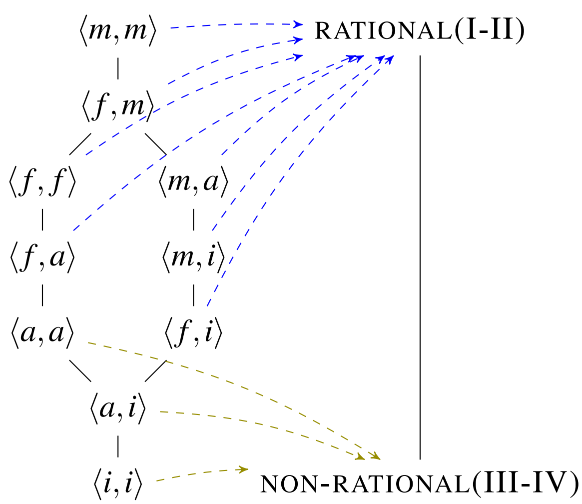
(55) *Resolution Rules in Archi*
a. I/II is used, if there is at least one rational conjunct (R);
b. Otherwise, III/IV is used (IR).

If rational (including masculine and feminine genders) resides higher on the hierarchy relative to the irrational, then all mappings are monotonic.

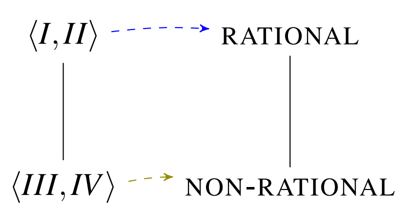
	MSC	FEM	ANIM	INANIM
MSC	R	R	R	R
FEM	R	R	R	R
ANIM	R	R	IR	IR
INANIM	R	R	IR	IR

Table 4.14: Patterns of gender resolution in Archi

(56) *Monotonic mappings in Archi*



(57) *Monotonic semantic mappings in Archi*



Even though this account seems to work, gender and animacy are not the defining factors in Archi resolution. If we reduce the structure of conjoined noun phrases to rational and irrational entities, then a simple pattern emerges.

Chibemba Let us conclude this section with an example from Bantu languages. The gender resolution patterns in Chibemba is representative of all Bantu languages. It is a convergent system where the genders in the singular determine genders in the plural.

Despite the complicated gender assignment classes in Chibemba, the resolution rules are rather simple. The system is rooted in the human/non-human distinction. Note that in Bantu, '1/2' gender means 'take class 1 agreements when singular and class 2 agreements when plural'.

<table>
<tr><th>SG</th><th>PL</th></tr>
<tr><td>1</td><td>2</td></tr>
<tr><td>3</td><td>4</td></tr>
<tr><td>5</td><td rowspan="3">6</td></tr>
<tr><td>14</td></tr>
<tr><td>15</td></tr>
<tr><td>7</td><td>8</td></tr>
<tr><td>9</td><td rowspan="2">10</td></tr>
<tr><td>11</td></tr>
<tr><td>12</td><td>13</td></tr>
</table>

Table 4.15: Genders in Chibemba

(58) Resolution Rules in Chibemba
a. 1/2 is used if all conjuncts are human (1/2)
b. 7/8 is used if none of the conjuncts are human (7/8)
c. 7/8 is used if mixed, although the comitative construction is preferable (7/8).

Based on the fact that the resolution rules in Chibemba are semantically motivated regardless of their noun class (/gender), we reduce the hierarchy to only include the human/non-human values. Note that this is exactly the semantic equivalent of the syntactic hierarchy we saw for French.

(59) *Monotonic mappings in Chibemba*

$$\begin{tikzcd}
\{h,h\} \arrow[r, dashed, bend left] \arrow[d, dash] & \textsc{human} \arrow[dd, dash] \\
\{h,nh\} \arrow[dr, dashed] \arrow[d, dash] & \\
\{nh,nh\} \arrow[r, dashed] & \textsc{non-human}
\end{tikzcd}$$

4.5 Conclusion

I have shown that even though gender assignment systems in different languages greatly vary, the emerging gender hierarchies are substantially the same and directly motivated by typological data. The distinction made between the syntactic and semantic gender systems boils down to those gender values that are used in the resolved plural forms. In a syntactic system, e.g., French and Slovenian, resolution rules are based on formal gender values. These systems mostly include feminine and masculine genders. As we saw, the nature of mappings remains the same as long as the feminine and masculine values reside on the two end nodes of the gender hierarchy. In a semantic system, e.g., Tamil and Archi, resolution rules are based on semantic values (RATIONAL

VS NON-RATIONAL), which results in a condensed hierarchy of gender that only includes those two values. Regardless of the hierarchy, in both system types, resolution rules follow monotonic mappings from base hierarchies to output forms. Similarly, Latin, as a mixed gender type, combines two subsystems based on a semantic feature (the property of being human). Essentially for our account, both semantic sub-types use monotonic mappings in the sense of Graf (2019a). The findings in this article lend further empirical support to the idea that monotonicity is a linguistic universal that extends beyond semantics.

Chapter 5

Person-Number Syncretism

Patterns of person-number syncretism provide robust data for studies that target typological gaps in morphosyntactic environments. In this chapter, I combine language-specific and cross-linguistic analyses of the data in an attempt to specify the restrictions on pattern attestability within the cross-cut of person and number features in languages with more than one type of syncretic pattern. The chapter argues that building a hierarchy of person-number values will be the first step in delimiting the range of possibilities. A further restriction comes from the approach introduced by Graf (2019a) in which the mappings from linguistic hierarchies to output forms should preserve the underlying hierarchical structure of the data by only allowing monotonic mappings. As was the case with previous chapters, monotonicity in this sense is introduced as an abstract formal universal on morphosyntactic phenomena.

5.1 Person-Number Paradigms

The set of linguistic values that are used to refer to speech act participants form a paradigm that often collapses person and number markers (Corbett, 2000, 64). Consider, by way of an illustrative example, the paradigm of English verbs. For the conjugation of English verb *write* in the past, we use the same form *wrote* in reference to the speaker, the addressee and to someone other than these two (e.g., *I wrote, you.*PL *wrote, my father wrote*). In the present tense, though, there is a minor complication with respect to the absent person in the singular that requires the suffix *-s* (e.g., *I write, you.*PL *write, my father writes*). The interaction of person and number, as evident in these examples, might imply a unified analysis of these features. For many linguists, however, the two features should be treated separately (Jespersen (1924, 212-215); Lyons (1968, 276-281); Croft (1990, 145-150); Cysouw (2003b, 101)). It is the intersection of the two that inspires the research presented here.

Person shows a three-way distinction: the speaker, the addressee, and the other. Following the literature, I use Arabic numerals to refer to these values:

(60) 1: reference to the speaker
2: reference to the addressee
3: reference to someone other than the speaker or addressee

The possible combinations of these three basic values are: 1+2 (minimal inclusive), 1+3 (exclusive), 1+2+3 (augmented inclusive), 2+3 (second person plural), 3+3 (third person plural), 1+1 (choral we), and 2+2 (only present audience). Cysouw (2003b) reports no grammatical form attested for the last two combinations.

Person values cross-cut the number paradigm (Corbett, 2000, 64-66, 83-87). Number is broadly divided into singular (SG) and non-singular. Non-singular consists in plural (PL) and restricted groups of more than one and usually less than five members (e.g., dual, trial, etc.). The cross-cut of number and person features introduces 1, 2, and 3 in the singular, 1+2, 1+3, 1+2+3, 1+1, 2+2 and 3+3 in the plural and other specified groups (e.g., dual, trial, etc.).

In order to remain within workable limits, in this paper, I take on the traditional view of a simple paradigm with 3 person and 2 number values. The combinations of these values render 6 cells in a paradigmatic table. The number of possible partitions with 6 cells is the Bell number of 6 which is 203 (§5.2) This means that there are 203 ways of arranging the contents of cells which range from *ABCDEF* (all cells have distinct contents) to *AAAAAA* (all cells have the same content). Table 5.1 shows the conjugation of the verb *go* in the past in Persian and English. The inflectional suffixes in Persian make it an *ABCDEF* type of paradigm, while English shows identical forms all along (*AAAAAA*).

Per	sg	pl
1	raft-am	raft-im
2	raft-i	raft-id
3	raft	raft-and

Eng	sg	pl
1	went	went
2	went	went
3	went	went

Table 5.1: Persian and English partial paradigms in the past for the verb ‘go’

The focus of this chapter is on pattern attestibility across paradigms in languages with more than one type of syncretic pattern. Surveying over 200 languages, I have collected an inventory of 22 such languages with 6-cell paradigms of person-number marking (i.e., languages that do not distinguish clusivity and restricted plural groups in their paradigms). As in previous chapters, my purpose is to understand if there is an underlying formal universal to restrict the types of syncretic person-number patterns that emerge in a language, especially given that there are 203 possibilities of person-number combinations to choose from. The analysis presented here is based on Graf’s proposal that posits monotonicity as a formal universal of morphosyntax (2019a). I have laid out the details of this proposal in Chapter 2. Let’s remind ourselves that based on this approach, morphosyntactic domains display an associated base hierarchy for the specific morphosyntactic feature(s) they are representing. The elements of this underlying hierarchy will be mapped to an identically ordered set of output forms. The prediction is that these mappings should all preserve the original ordering of the base hierarchy, or in other words, they should be monotonic.

In the rest of this paper, I start by situating the problem in §5.2. I explain the approach taken here by identifying the the hierarchies we can use for person-number combinations (§5.3). I show that the same monotonic restriction that we saw with tense (Chapter 3) and gender (Chapter 4) applies to attested syncretism of person-number in languages with more than one such pattern (§5.4). This means that if a languages has, say, 8 patterns of syncretism, like Burushaski, all of those patterns should be monotonic under a specific hierarchy of linguistic person and number. However, languages can choose the hierarchy they use from 6 possible configuration (§5.5). I will conclude the chapter in §5.6.

5.2 Patterns

A 6-cell paradigm accommodates 203 possible patterns. This is because the number of distinct partitions for a set with *n* elements is the Bell number (B_n), and $B_6 = 203$. In other words, the set of nonempty, pairwise disjoint subsets of a 6-cell paradigm has 203 members. Figure 5.1 shows all these possibilities: within each hexagon, dots indicate entities with distinct realizations and the positions connected by lines are homonymous.

In order to find an explanation for the types of syncretism a language allows in the realization of its person-number features, as explained before, I follow Graf's algebraic characterization of attested patterns (Graf, 2019a). The core insight in this approach is that an algebraic perspective reveals the hidden structure of morphosyntactic associations: morphosyntactic scales and hierarchies correspond to specific algebraic structures which are derived from some universally fixed order. Once the hierarchy of the understudied category is set, then all that is left is to see whether the mappings from this hierarchy to output forms are monotonic. In §5.3 I explore the nature of the hierarchies that encompass both person and number.

5.3 Person-Number Hierarchies

Originally, the person hierarchy was proposed as the upper part of an animacy hierarchy: Smith-Stark (1974, 662-665) ranked speaker above addressee, while Silverstein (1976, 122) ranked addressee above speaker.

(61) *Animacy hierarchy*
$1 > 2 > 3 > \textit{kin} > \textit{human} > \textit{animate} > \textit{inanimate}$

In his discussion on person values, Zwicky (1977, 718) also takes $1 > 2 > 3$ to be a universally robust hierarchy. Meanwhile, Plank (1985, 123-152) and Comrie (1989, 198) believe that there is no consistent ranking of speaker and addressee through the world's languages, and that a better hierarchy is SPEECH ACT PARTICIPANT > 3 (Macaulay, 2005). Croft (1990, 149) shows the

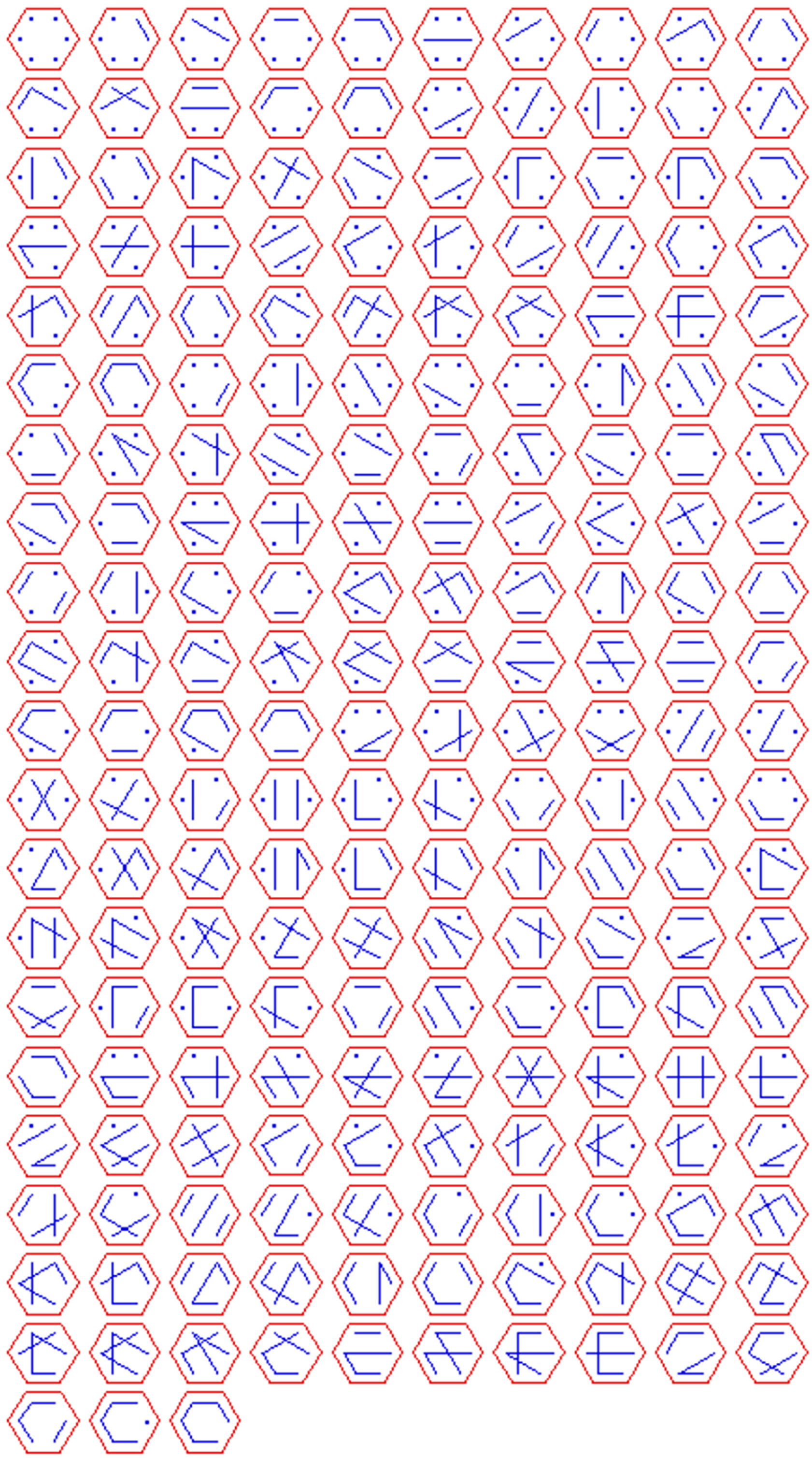


Figure 5.1: 203 possible partitions of 6 elements

same thing for various sub-domains of each language. Cysouw (2003b, 165) interprets the person hierarchy as two nested hierarchies: The first part of the hierarchy ranks speaker and addressee above other participants. The second part of the hierarchy internally distinguishes speaker as ranked higher than addressee.

With number, things are less clear. While grammatically singular is, in most cases, unmarked and plural is marked with an inflectional marker, Sauerland (2008) takes plural to be semantically unmarked in all languages. On the other hand, Greenberg's Universal 34, $singular < plural < dual < trial$, implies that it is the singular that is the least marked. Malouf et al. (2015) show that an associative learning study of grammatical number motivates the emergence of the Number Hierarchy as an implicational universal, supporting Greenberg's Universal 34.

Drawing on the diverse nature of the data presented in the literature, the combination of person and number markings can be viewed with six basic hierarchies. There are three possibilities for the person hierarchy: an absolute ordering of the values ($1 > 2 > 3$), unordered speech act participants ($1|2 > 3$), and first person ordered higher than the other two ($1 > 2|3$). Likewise, there are two possibilities for ordering the number values: SG>PL and PL>SG. The cross product of the three person hierarchies and the two number hierarchies result in six person-number hierarchies as shown below. In all of the following hierarchies, 1 is high in the hierarchy and 3, as a clearly marked form, resides at a lower part.

With respect to person-number combinations, one can speculate 3 types of languages:

(i) those that are only sensitive to the person hierarchy and allow any ordering of number values;

(ii) those that are only sensitive to the number hierarchy regardless of the person hierarchy;

(iii) those that require a combination of both hierarchies.

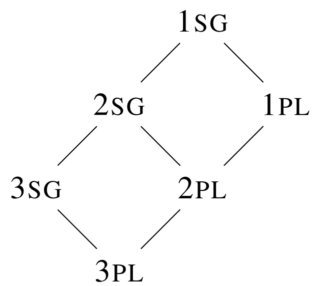


Table 5.2: SG>PL, 1 > 2 > 3

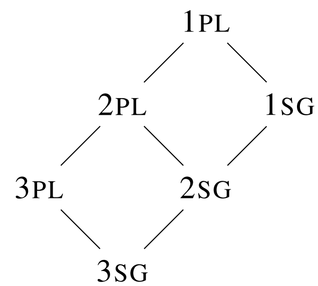


Table 5.3: PL>SG, 1 > 2 > 3

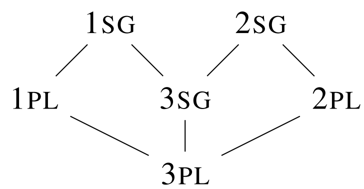


Table 5.4: SG>PL & 1|2 > 3

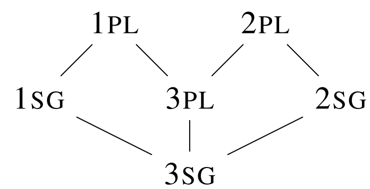


Table 5.5: PL>SG & 1|2 > 3

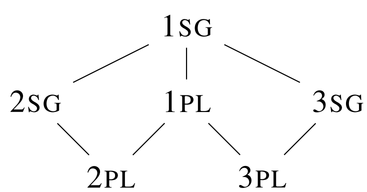


Table 5.6: SG>PL & 1 > 2|3

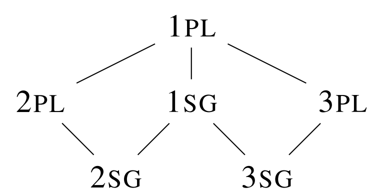


Table 5.7: PL>SG & 1 > 2|3

In the next section, I first introduce the structure of the typological data and then try to discover how languages fit into this picture.

5.4 The structure of the data

The data for this study, naturally, comes from the ways in which people are referred to by personal pronouns and inflectional affixes. In order for the data to be as comprehensive as possible, I have included all possible types of form-meaning combinations in a language regardless of the default markings, i.e., I have included "exceptional" markings that are restricted to a subset of paradigms (e.g., the present tense paradigm) specific to a certain domain (e.g., tense, aspect or gender). Since this is not a cross-paradigmatic study, though, I have not included patterns of cross paradigmatic syncretism, i.e., I have ignored cases of syncretism between, say, a cell in the present tense and another cell in the past tense. I have also ignored the pragmatic usage of pronominal forms. These are cases like the German pronoun /zi/ which is the polite second person pronoun as well as third person pronoun (Zwicky, 1977, 716). Similarly, in Persian, I have ignored the polite use of 2PL *šomā* to refer to 2SG.

The database for the study was built using cross-linguistic data from the Surrey Syncretism database (Baerman, 2002b), the Surrey Person Syncretism database (Baerman, 2002a), Baerman et al. (2005), Cysouw (2003b), Corbett (2000), Stump (2001), WALS online (Dryer and Haspelmath, 2013), and grammar books of individual languages. You can find the cross-linguistic data used in this chapter in this github directory.[1]

Many of the languages in the set show only one pattern of syncretism in person-number combinations. For the purposes of this paper, I have put those languages aside and have focused on languages that use different patterns of syncretism in different domains. Burushaski, a language isolate spoken in northern Pakistan, for instance, uses 8 different patterns of syncretism, each of them within a specific context. In some cases, there are languages that show free variation in specific paradigm cells. The Nilo-Saharan Bagirmi, for example, can use two forms for 1PL in the definite aspect of verbs (Stevenson 1969 as reported in the Surrey Person Syncretism database). Depending on the form chosen, the syncretic pattern changes (Table 5.8). If *sa* is used, then 1PL is syncretic with both 2SG and 3PL. If instead *saki* is used, then there are two syncretic patterns in this paradigm: one between 2SG and 3PL, and second between 1PL and 2PL.

	SG	PL
1	m-sa	sa (-ki)
2	sa	sa-ki
3	n-sa	sa

Table 5.8: Bagirmi definite aspect for ‘eat’

There are languages, like the Sko language Vanimo, where the syncretic pattern involves a specific gender. This mostly happens in the 3SG cell. In Table 5.9, the masculine form of the 3SG is syncretic with 1PL and 3PL, but the feminine form does not make the same pattern.

	SG	PL
1	ve	hve
2	pe	ve
3.MSC	hve	hve
3.FEM	se	hve

Table 5.9: Vanimo verb for ‘sit’

With this general introduction to the methodology, I next present the typological data.

[1] https://github.com/somoradi/somoradi/tree/master/ThesisAppendix

5.5 Language typology

Let us assume that the set *PN* below is an ordered set the same way that there are ordered cells in a traditional paradigm.

(62) $PN = \{1\textsc{sg}, 2\textsc{sg}, 3\textsc{sg}, 1\textsc{pl}, 2\textsc{pl}, 3\textsc{pl}\}$

In what follows, I use this fixed order to show the patterns of syncretism for each piece of data. Additionally, I use the letters *a*–*f* to represent the content of each paradigmatic cell.

There are 22 languages in the typological sample that I have gathered with more than one pattern of syncretism in marking person-number combinations. Vanimo with 12 patterns has the highest number of patterns followed by Burushaski with 8 patterns. Table 5.10 shows the number of patterns found in our language sample. Few languages show more than four patterns of syncretism across their paradigms, with most of them having only two such patterns.

Patterns #	Languages
2	Dongola, Dutch, German, Hindi, Ibibio, Ika, Orokaiva, Tol, Waskia, Yukaghir
3	Gothic, Irish, Nubian, Romanian
4	Daga, French
5	Bagirmi, English, Lak, Rongpo
8	Burushaski
12	Vanimo

Table 5.10: Frequency of pattern count in each language

In Chapter 3, we saw that the typological data can be explained in terms of the monotonicity requirement over a single tense hierarchy. With gender resolution, things were a bit different. Even though the basic idea for a gender hierarchy was the same across languages, the shape of the hierarchy would change a bit based on typological requirements. The other fundamental difference between the tense and the gender data was that with gender we introduced a 2-dimensional structure which would take the gender value of two arguments to arrive at a single value for the predicate (Chapter 4). Here we are facing the same 2-dimensional structure with the difference that they come from two different features: person and number. Now the idea is to check the patterns found in each language across the proposed hierarchies that combine person and number and see if the mappings still follow the monotonicity requirement. As we will see, patterns of syncretism within each language only produce monotonic mappings over one of the proposed hierarchies. Still languages are free to choose from among the six possible combinatory hierarchies. Let's see this in practice with data from Yukaghir, English, Bagirmi, and Vanimo. All other languages listed in Table 5.10 also follow the monotonicity account.

5.5.0.1 Yukaghir

Yukaghir, a language spoken in the Sakha region of Russia, has two patterns of syncretism based on inflectional suffixes in its Aorist paradigm (Baerman 2002b based on data from Maslova 1999; Nikolaeva & Xelimskij 1997).

	Aorist Intransitive Subject focus	
	SG	Pl
1	-l	-l
2	-l	-l
3	-l	- il

	Aorist Transitive Object focus	
	SG	PL
1	-me	-l
2	-me	-mek
3	-mele	- i-mele

Table 5.11: Yukaghir Aorist paradigm (Baerman, 2002b)

Within the intransitives, those verbs that have *subject focus* show *aaaaab*. In the paradigm of transitive verbs, the *object focusing* verbs show *aabcde*.

Both of these patterns demonstrate monotonic mappings over a hierarchy of SG>PL. In *AAAAAB*, there are 2 output forms *a* and *b* and all that is required is for 3PL to be at one of the end nodes. Since none of the hierarchies allow 3 to be at the higher node, it should follow that SG>PL.

In order for *AABCDE* to be monotonic, in addition to SG>PL, the language should rank 1 higher than 2 & 3, but 2 & 3 should be unordered with respect to each other.

All these configurations can be captured in Yukaghir's preferred hierarchy which is SG>P; $1 > 2|3$.

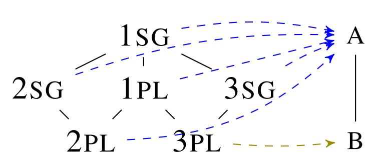


Figure 5.2: Monotonic mappings in Yukaghir (*AAAAAB*) over SG>PL & $1 > 2|3$

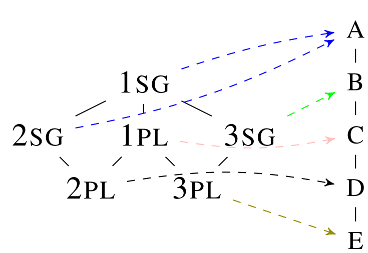


Figure 5.3: Monotonic mappings in Yukaghir (*AABCDE*) over SG>PL & $1 > 2|3$

5.5.0.2 English

English shows syncretic patterns in almost all of its paradigms. Table 5.12 shows the possible forms of paradigmatic combinations of person and number in this language.

Present		
	SG	PL
1	go	go
2	go	go
3	goes	go

Past		
	SG	PL
1	went	went
2	went	went
3	went	went

Copula.PRS		
	SG	PL
1	am	are
2	are	are
3	is	are

Copula.PST		
	SG	PL
1	was	were
2	were	were
3	was	were

Personal Pronouns		
	SG	PL
1	I	we
2	you	you
3	she/he	they

Table 5.12: English Person-number combinations

Based on this table, there are five patterns of syncretism in English. These include *AAAAAA*, *AABAAA*, *ABCBBB*, *ABABBB*, *ABCDBE*. The person-number hierarchy that can produce monotonic mappings for all these patterns is PL>SG & $1|2 > 3$.

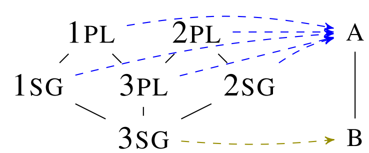


Figure 5.4: Monotonic mappings in English (*AABAAA*) over PL>SG & $1|2 > 3$

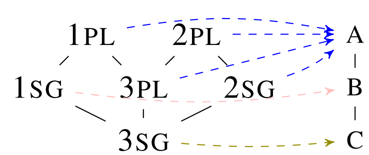


Figure 5.5: Monotonic mappings in English (*ABCBBB*) over PL>SG & $1|2 > 3$

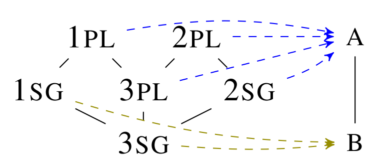


Figure 5.6: Monotonic mappings in English (*ABABBB*) over PL>SG & $1|2 > 3$

5.5.0.3 Bagirmi

Bagirmi belongs to the Nilo-Saharan family and is spoken in Chad.

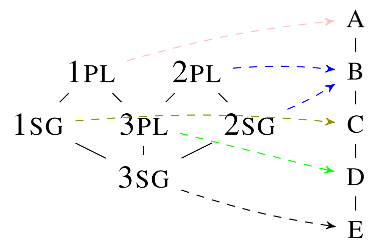


Figure 5.7: Monotonic mappings in English (*ABCDBE*) over PL>SG & $1|2>3$

<table>
<tr><td>‘eat’</td><td>indefinite aspect</td><td>definite aspect: C-initial stem</td><td>definite aspect: V-initial stem ‘see’</td></tr>
<tr><td>1sg</td><td rowspan="4">käsa</td><td>m-sa</td><td>m-ak(a)</td></tr>
<tr><td>3sg</td><td>n-sa</td><td>n-ak(a)</td></tr>
<tr><td>2sg</td><td rowspan="2">sa</td><td>ak(a)</td></tr>
<tr><td>3pl</td><td>j-ak(a)</td></tr>
<tr><td>1pl</td><td>kä-sa(-ki)</td><td>sa(-ki)</td><td>j-aka(a)/j-ak-ki</td></tr>
<tr><td>2pl</td><td>kä-sa-ki</td><td>sa-ki</td><td>ak-ki</td></tr>
</table>

Table 5.13: Bagirmi paradigm (Baerman, 2002b)

The data shows a number of syncretic patterns which are mostly conditioned by TAM markers. We can detect three patterns of syncretism in the indefinite aspect: $1sg = 2sg = 3sg = 1pl = 3pl$ if 1PL is marked by *käsa*, but if 1PL is marked by *käsaki*, then the language reveals a couple more patterns: $1sg = 2sg = 3sg = 3pl$ and $1pl = 2pl$.

Within the definite aspect, the C-initial stems also show two kinds of syncretic patterns: if 1PL is marked by *sa*, then this form is shared by 2SG and 3PL ($2sg = 1pl = 3pl$). If, on the hand, *saki* is used for 1PL, then it is syncretic with 2PL ($2sg = 3pl$ and $1pl = 2pl$).

Similarly, in the V-initial definite aspect there is $1pl = 3pl$ where both forms use the *jaka* marker.

Pattern	Domain
ABCBDB	DEFINITE C-INITIAL
ABCDDB	DEFINITE C-INITIAL
AAAABA	INDEFINITE
AAABBA	INDEFINITE
ABCDED	DEFINITE V-INITIAL

Table 5.14: Bagirmi patterns of syncretism

So all in all, in Bagirmi, the indefinite aspect shows the patterns *ABCBDB*, *ABCDDB*, *ABCDED*, while we can find *AAAABA* and *AAABBA* in the indefinite aspect. One of the patterns (*ABCDED*) is monotonic over any of the hierarchies, and two of them (*ABCDDB* and *AAABBA*) are monotonic over any hierarchy that posits plural over singular in the number hierarchy. Yet the two remaining patterns are only monotonic over two hierarchies: either S>P; $1 > 2|3$ or P>S; $1|2 > 3$. Given this picture we can conclude that the deciding factor in Bagirmi is the number hierarchy which favors P>S. In order to have an account that works for all the patterns, P>S; $1|2 > 3$ is the default person-number hierarchy in this language.

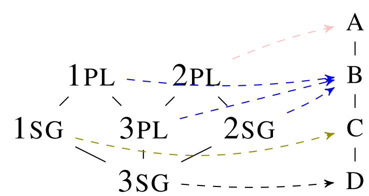


Figure 5.8: Monotonic mappings in Bagirmi (*ABCDBD*) over PL>SG & $1|2 > 3$

5.5.0.4 Vanimo

Vanimo is a Skou language of Papua New Guinea spoken in areas around the Papua New Guinea–Indonesian border. The data in (5.15) comes from Baerman (2002b) which is based on Foley and Foley (1986) and Laycock (1975).

<table>
<tr><td></td><td colspan="4">Foley 1986</td><td colspan="6">Laycok 1975</td></tr>
<tr><td></td><td>‘sit’</td><td>‘do, make’</td><td>‘hit them’</td><td>‘put’</td><td>‘eat’</td><td>‘go’</td><td>‘come’</td><td>‘hear’</td><td>‘sit’</td><td>‘see’</td></tr>
<tr><td>1sg</td><td rowspan="2">ve</td><td rowspan="2">lå</td><td rowspan="2">yí</td><td rowspan="3">hú</td><td>å</td><td>a</td><td rowspan="3">lü</td><td rowspan="2">lõ</td><td>hve o</td><td>hve</td></tr>
<tr><td>2pl</td><td>å*</td><td>a*</td><td>hve õ</td><td>hve</td></tr>
<tr><td>3sg.m</td><td rowspan="3">hve</td><td>hlå</td><td>hyí</td><td>hå</td><td>ha</td><td>hlõ</td><td>hve mo</td><td>h hve</td></tr>
<tr><td>1pl</td><td>de</td><td>ní</td><td>dú</td><td>nå</td><td>na</td><td>dü</td><td>nõ</td><td>hve no</td><td>n hve</td></tr>
<tr><td>3pl</td><td>di</td><td rowspan="3">sí</td><td>tú</td><td>då</td><td>ya</td><td rowspan="2">lü</td><td>sõ</td><td>hve mo</td><td>ñ hve</td></tr>
<tr><td>3sg.f</td><td>se</td><td>pli (hvi)</td><td>pú</td><td>bå</td><td>va</td><td>tõ</td><td rowspan="2">pe mo</td><td rowspan="2">m pe</td></tr>
<tr><td>2sg</td><td>pe</td><td>blå</td><td>bú</td><td>må</td><td>ma</td><td>blü</td><td>mlõ</td></tr>
</table>

Table 5.15: Vanimo verb paradigm (Baerman 2002)

This data makes for a complicated picture for individual verbs. In (5.16), I list the patterns of syncretism that emerge from this data.

Vanimo presents the most complex picture among the languages under study. In this language, except for *ABCCAC*, all other patterns require P>S. *ABCCAC* is the pattern that Foley and Foley (1986) associates with the masculine conjugation of the verb for ‘sit’. The account that Laycock (1975) presents also has a pattern for this verb, yet there the documented pattern is *ABCDEC*. It is most likely that this second pattern is indeed the correct form of the verb, because in that case the language is straightforwardly P>S.

Among the remaining patterns, *ABCDAD* (5.9), *ABACAD* (5.11), and *ABACAA* (5.10) all require P>S & $1 > 2|3$. Any relative order of $1|2$ or $2|3$ will work for *ABACDE*. The rest of the patterns

Foley 1986	
Pattern	**Verb**
ABCCAC	sit.msc
ABCDAD	sit.fem
ABCDAE	do
ABCDAB	hit.msc
ABBCAB	hit.fem
ABACAD	put.msc
ABACDE	put.fem

Laycock 1975	
Pattern	**Verb**
ABACAA	come
ABCDAE	hear
ABCDEC	sit.msc
ABBCDE	sit.fem
ABBCAD	see.fem

Table 5.16: Vanimo syncretic patterns

only require a higher position of plural over singular in the number hierarchy, no matter what the person hierarchy is.

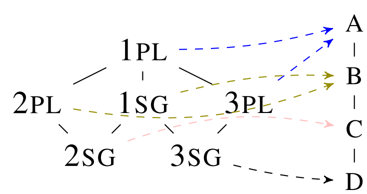


Figure 5.9: Monotonic mappings in Vanimo (*ABCDAD*) over PL>SG & $1 > 2|3$

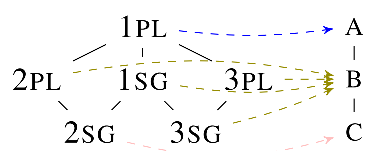


Figure 5.10: Monotonic mappings in Vanimo (*ABACAA*) over PL>SG & $1 > 2|3$

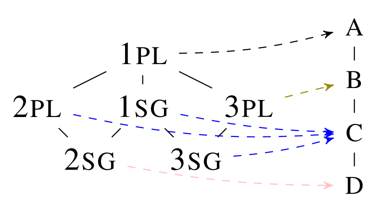


Figure 5.11: Monotonic mappings in Vanimo (*ABACAD*) over PL>SG & $1 > 2|3$

5.5.0.5 Other languages

Illustrating the whole range of patterns in all the 22 languages makes reading this chapter a boring task. I leave reflecting on the introduced concept to the curious reader. However, in the following table (5.17), I have listed the attested syncretic patterns in all the sample languages. I have also proposed an associated hierarchy which is motivated by the data in each language.

Surveying these languages, we can see a gamut that ranges from 'No Restriction' (i.e., the mappings over any of the available 6 hierarchies are monotonic) to hierarchies that only specify a number preference (e.g., PL>SG) to those which add a person hierarchy as well (e.g., PL>SG; $1|2 > 3$).

At a closer look, we can find some general tendencies with the structure of hierarchies in Table 5.17. Eleven of the languages strictly prefer plural to be ranked above singular, and only 4 languages strictly prefer singular over plural. Except for the three languages that do not impose any restrictions, none of the remaining languages allow a strict hierarchy of $1 > 2 > 3$. The frequency of $1|2$ and $1 > 2$ is the same and neither one is preferred over the other. Another interesting observation is that with PL>SG, in eight cases the person hierarchy is $1|2$. With a number hierarchy of the type SG>PL, on the other hand, only $2|3$ is used. These observations might help us better understand the structure of person-number marking in a larger study of these systems

5.6 Conclusion

Using the monotonicity approach, in this chapter, I showed that for languages with more than one type of person-number syncretism pattern, the restraining factor lies in the nature of the person-number hierarchy. Some languages prefer a more robust number hierarchy, while others are mostly concerned with the person ordering. Yet there are more restricted types of languages that are sensitive to both hierarchies. No matter which hierarchy a language adopts, the output patterns should preserve the internal structure of that hierarchy. The monotonicity principle is introduced to check this alignment.

The nature of the hierarchies used in this chapter are intrinsically different from those introduced for tense (Chapter 3) and gender (Chapter 4). This is due to a number of reasons. One is that in person-number hierarchies we are dealing with two separate linguistic categories, each with their semantic intricacies and a vast variety of ways they are used cross-linguistically. Additionally, the amount of data analyzed in this chapter was collected from a huge number of languages, mostly due to abundant documentations of person and number markers. In the next chapter, I compare the different types of hierarchies we have seen so far and discuss possible implications.

Language	**Patterns**	**Hierarchy**
Bagirmi	abcbdb; abcddb; aaaaba; aaabba; abcded	PL>SG; $1\|2 > 3$
Burushaski	aabccc; abcdee; abcddd; abcdde; abcbbb; abcdbb; abbcbb; abbccc	PL>SG; $1 > 2\|3$
Daga	abcade; abcdee; abcdec; abacba	PL>SG
Dongola	abbccd; aaaaab	SG>PL
Dutch	abbccc; abacdc	PL>SG; $1\|2 > 3$
English	aaaaaa; aabaaa; abcbbb; ababbb; abcdbe	PL>SG; $1\|2 > 3$
French	aaabca; abbcdb; abbcac; aaabcd	PL>SG; $1\|2 > 3$
German	abcdcd; abacdc	PL>SG; $1\|2 > 3$ or SG>PL; $1 > 2\|3$
Gothic	abcdce; abaccc	PL>SG; $1\|2 > 3$ or SG>PL; $1 > 2\|3$
Hindi	abbcdc; abbcbc	PL>SG; $1\|2 > 3$
Ibibio	abbcdd; aabbbb	SG>PL; $1 > 2\|3$
Ika	abaccd; abbbbb	SG>PL; $1 > 2\|3$
Irish	abbcbb; aaabaa; abcdce	PL>SG; $1\|2 > 3$
Lak	aabccc; aabccd; aabccb; abbabb; abbcbb	No Restriction
Nubian	abcade; abbccd; abbccb	PL>SG
Orokaiva	abcded; aabaca	PL>SG; $1 > 2\|3$
Romanian	abcade; abcdec; abcdea	PL>SG
Rongpo	abbccc; abcdde; abcddd; abcccc; abbbbb	SG>PL
Tol	aabcde; abbcde	No Restriction
Vanimo	abccac; abcdad; abcdae; abcdab; abbcab; abacad; abacde; abacaa; abcdae; abcdec; abbcde; abbcad	PL>SG; $1 > 2\|3$
Waskia	aabccc; aabccd	No Restriction
Yukaghir	aaaaab; aabcde	SG>PL; $1 > 2\|3$

Table 5.17: Languages and their hierarchies

Chapter 6

Conclusion

Grammatical variations are known to be highly variable and at the same time characteristically limited. This dissertation aimed to identify an underlying substantive universal in certain domains of morphosyntax that would explain the nature of paradigmatic gaps. By analyzing a wide range of cross-linguistic typological data, this thesis has shown how the mathematical notion of monotonicity can be used to delimit paradigmatic gaps. Effectively, I have used the monotonicity account developed by Graf (2019a). There are two basic requirements to this approach: a fixed underlying hierarchy (a person hierarchy, case hierarchy, etc.), and the requirement that the mappings from these hierarchies to output forms must be monotonic. Within this framework, I have shown the range of variation in three domains: tense-stem syncretism (Chapter 3), resolved agreement (Chapter 4), and person-number syncretism (Chapter 5). My proposed hierarchies for each domain are listed in Table 6.1.

There are two main points to be discussed here: one regarding the hierarchies and one about the nature of monotonicity as a universal constraint. First is a general note about the data from which the linguistic hierarchies are built or against which they are tested. An important risk associated with typological studies has to do with the reliability of the data. As mentioned above, the data is collected from the relevant literature and in each case I rely on the analysis of the data proposed by the referred sources. Data gathering parameters of different projects are mostly related to the questions that a research program aims to answer. This makes many kinds of documentation efforts biased, if accurate at all. Although there is good reason for being concerned about the methods of language documentation, there is no doubt that the linguistic theory and practice are building up on the same kind of data. The strategy I take to be highly commendable is to be accurate and straightforward about the data and revise one's work with any piece of new data or analysis that renders itself for a closer scrutiny. As such the proposed hierarchies are open for revisions should future data shed any doubt on the accuracy of the patterns.

There is a massive literature on linguistic universals and the implicational and prominance hierarchies that arise from those universals. These hierarchies are powerful tools in analyzing linguistic phenomena because they have considerable predictive and restrictive power. In explaining the importance of hierarchies, Lockwood and Macaulay (2012, 432) point out three possible

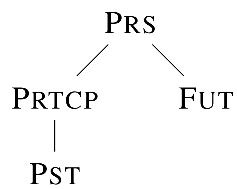
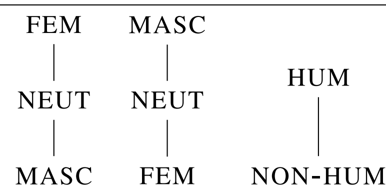
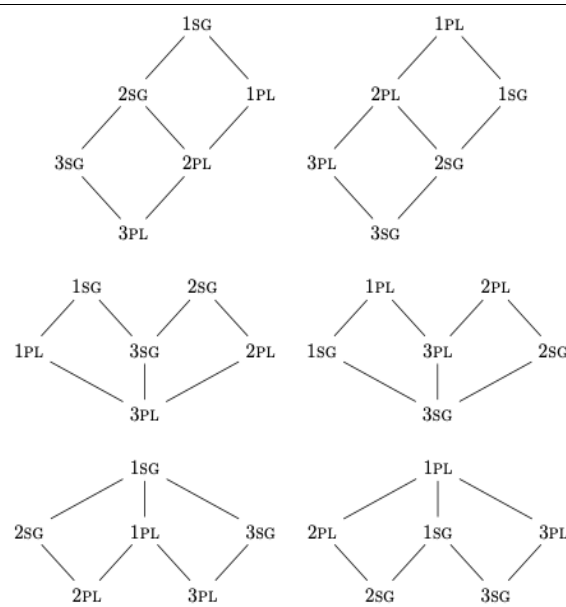
<table>
<tr><th>Phenomenon</th><th>Hierarchy</th></tr>
<tr><td>Tense</td><td>
</td></tr>
<tr><td>Gender</td><td>
</td></tr>
<tr><td>Person-Number</td><td>
</td></tr>
</table>

Table 6.1: Proposed hierarchies for each phenomenon

perspectives. They first point to phenomena that can be best described by hierarchies in individual languages. The Accessibility Hierarchy (Keenan and Comrie, 1977) and Agreement Hierarchy (Corbett, 1979) are examples of hierarchies that explain why certain syntactic and semantic patterns are observed in a language while others are not. The second perspective has to do with the typological interest of hierarchies. In this sense they show similarities among languages and pose puzzles for typologists who try to explain the possible patterns of human language. Lastly, hierarchies pose theoretical problems "in that they encode relationships between arguments which are difficult to model under current assumptions about features, agreement, and the like" (Lockwood and Macaulay, 2012, 432).

Not all typologists, however, are in favor of implicational hierarchies. Cysouw (2003a, along with the ensuing discussions in Dryer (2003); Plank (2003)) raises the question of viabality of hierarchies in light of statistical tests. In a frequency cline, "absolute frequencies have to be compared with values as expected by pure chance", he says (Cysouw, 2003a, 100). He also rejects any unidirectional dependency between parameters because relationships are due to interactions, and all significant interactions are bidirectional. Cysouw, however, accepts that traditional implicational universals and implicational hierarchies belong to a special class that can be best described as a markedness cline. Based on the number hierarchy, for instance, if a language has a dual number value, then it also has a plural, and dual is more marked than plural. Regardless of what term one uses to refer to the kind of relationship implied here, this is the type of hierarchy I have used in this dissertation. In fact the hierarchies used in this dissertation are all well-grounded in this sense and their robustness comes from their wide usage across languages.

Cysouw's observation regarding the interaction between parameters hints at an important fact about hierarchies: not all hierarchies are linear, asymmetrical, one-dimensional arrangements, and in fact they can have complex, partial structures. Graf (2019a) and Bárány (2021) also use partial orders to arrive at linguistic hierarchies for case, noun-stem allomorphy, the Person Case Constraint, and the Gender Case Constraint. We see such hierarchies with partial orders over and over in this dissertation as well. The tense hierarchy I propose in Chapter 3 uses the complex arrangement of temporal relations explained by (Reichenbach, 1947) in order to arrive at a hierarchy of tense used in verbal paradigms. The 2-dimensional structures discussed for gender-gender resolution (resolved gender agreement in Chapter 4) and for person-number combinations (Chapter 5) are inherently more complex and require both linear and partial orders, depending on the nature of each system. Among the hierarchies introduced in this dissertation, the tense hierarchy and the person-number hierarchies are partially ordered structures. Whereas gender resolution rules can form both linear and partial structures depending on the number of gender values that are involved in resolution processes.

Do we need one single hierarchy for each domain or can languages choose? Among the hierarchies introduced here (Table 6.1), the one proposed for tense appears to work universally across all languages with morphological realization of the three main tenses, i.e., present, past, and future. The solid logic behind this hierarchy comes from the temporal relations developed and discussed by Reichenbach (1947).

With gender matters are more interesting. Here we might think that we need to distinguish between the more Indo-European type of gender systems (including feminine, masculine, and possibly neuter) and gender systems that are strictly semantic. But underlyingly both hierarchies follow the same logic. They are both linear. In 3-gender systems with feminine, masculine and neuter, there is no strict way of ordering feminine and masculine with respect to each other; the only requirement is that the neuter should reside between those two. For languages with semantic resolution, even though there are multiple classes of gender assignment, the resolution is based on the human vs. non-human, rational vs. irrational, or human vs. neuter distinction (in Table 6.1 I have only included the human vs. non-human hierarchy, but they all work the same way). Mixed type gender resolution systems use partial orders because they add a semantic flavor to a (mostly) syntactic hierarchy of gender. Their resolved form, however, is in the form of a linear order of the base gender hierarchy they use (e.g., a syntactic hierarchy). See the Romanian hierarchy repeated below (6.2) where the interaction of animate and inanimate factors makes for more gender combinations.

$$\begin{tikzcd}
 & \{mA,mA\} \arrow[d, dash] & \\
 & \{mA,mI\} \arrow[dl, dash] \arrow[dr, dash] & \\
\{mA,fA\} \arrow[d, dash] & & \{mI,mI\} \arrow[d, dash] \\
\{mA,fI\} \arrow[d, dash] & & \{mI,fA\} \arrow[d, dash] \\
\{mI,fI\} \arrow[dr, dash] & & \{fA,fA\} \arrow[dl, dash] \\
 & \{fA,fI\} \arrow[d, dash] & \\
 & \{fI,fI\} &
\end{tikzcd}$$

Table 6.2: Romanian gender resolution hierarchy (A: animate; I: Inanimate)

The story of person-number hierarchies is somewhat different from tense and gender. The hierarchy itself is a result of the cartesian crossproduct of two base hierarchies: person and number. The prior literature motivates 2 hierarchies for number and 3 for person; together they make for six mixed hierarchies. Since the data did not favor one of theses hierarchies as THE hierarchy, I included all of them and played with all the possibilities. The conclusion was that languages can choose one of them, with the requirement that all their patterns of syncretism are monotonic mappings over the chosen hierarchy.

Now a central question that remains to be answered is why monotonicity should hold as the basic requirement for patterns to emerge? Monotonic patterns emerge all over language, in phonology (No Crossing Constraint), in morphology and syntax (as shown here and in Graf (2019a), Graf (2020)), and most importantly in semantics. It is widely accepted that in many areas of semantic analysis, monotonicity plays a major role to the extent that Steinert-Threlkeld and Szymanik (2019) refer to it as a *semantic universal*, and "semantic universals arise because expressions satisfying the universal are easier to learn than those that do not" (Steinert-Threlkeld and Szymanik, 2019, 1). Steinert-Threlkeld and Szymanik (2019) explain how all simple determiners are monotone. Furthermore, the results of an experiment they run on neural networks (Steinert-Threlkeld and Szymanik, 2019, 20) reports that:

> [b]oth upward- and downward monotone quantifiers are learned significantly more quickly than a corresponding non-monotone quantifier by an LSTM network. In the context of the present study, this supports the argument that the MONOTONICITY UNIVERSAL holds because monotone quantifiers are easier to learn.

Monotonicity can also be regarded as a major 'third factor'. Chomsky (2005) famously refers to three factors in attaining languages: genetics, experience, and language-independent factors. This third factor is important in that it provides more principled explanation of linguistic phenomena. Within this class of factors, Chomsky singles out principles of efficient computation as the most significant for computational systems such as language (Chomsky, 2005, 6). Language is a means of abstract or productive thinking and it would be no surprise if it uses abstract formal tools to do so.

Future studies on substantive universals and formal approaches to classifying typological gaps will benefit from the methodologies used in this dissertation for data interpretation and the varied ways it has employed to construct hierarchies. To better understand the implications of the results reported here, future studies could address other areas of language where data can be restated in terms similar to mathematical functions. Since a large amount of the formal linguistic knowledge is about making associations and predicting patterns, there seems to be a perfect ground for similar studies. Even though monotonicity is presented as an abstract constraint on pattern attestibility, further research is needed to determine the causes of this cognitive requirement, the effects it might have on our generative capacity, and possible relationships between this requirement and other cognitive constraints the human brain posses.

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