Prosody and Recursion in Coordinate Structures and Beyond*

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April 2, 2007

Abstract

This paper argues that generalizations about prosodic phrasing are recursive in nature. Initial evidence comes from the fragment of English consisting only of proper names and *and* and *or*. A systematic relation between the semantics, the syntactic combinatorics, and the prosodic phrasing of these coordinate structures can be captured by recursively combining the prosodies (represented as relational metrical grids) of its parts, in tandem with assembling the compositional meaning of the expression. Alternative edge-based approaches to prosodic phrasing fail to capture the recursive nature of the generalization, a result independent of whether or not prosodic representation itself is assumed to be recursive. The presented model is argued to generalize beyond the coordinate fragment, despite two types of apparent counterexamples: Structures that are prosodically flat but syntactically articulated, and structures with an apparent mismatch between prosody and syntax, as epitomized by the famous *cat that chased the rat that stole the cheese* (Chomsky, 1965, Chomsky and Halle, 1968). Closer inspection reveals that the syntax might actually be quite in tune with prosody in both cases.

1 Recursion and Prosodic Compositionality

Grammar is recursive in that it allows the speaker of a language to combine basic elements to create meaningful expressions, and each output can in turn be used as a building block in a yet more complex expression. Every new output must be assigned a semantic interpretation and a set of phonological instructions specifying how to pronounce it. Coordinate structures provide a simple illustration of the recursiveness of grammar. Two or more constituents can be combined to form a new constituent by connective functors such as *and* and *or*, each coordinate can itself consist of a coordinate structure:[1]

(1) a. Lysander or Demetrius.

b. Hermia and (Lysander or Demetrius).

*This chapter is based on two chapters from my MIT dissertation (Wagner, 2005b). In the meantime, I have received helpful feedback from John Bowers, Wayles Brown, Abby Cohn, Jon Gajewski, Mats Rooth, an anonymous reviewer for the Cornell working papers in Linguistics, and from audiences at the University of Connecticut, at McGill University, at Goethe-University in Frankfurt and the Psychology Department at Cornell.

[1] I will use the terminology employed in Huddleston and Pullum (2001), who refer to *and* and *or* as the 'connectors' of coordinate structures and the parts they conjoin as the 'coordinates'.

c. Helena or (Hermia and (Lysander or Demetrius)).

Different bracketings of coordinate structures can affect the truth-conditions of an expression. Consider the following two statements, which differ only in the bracketing of the expression to the right to the equivalence symbol. While (2a) is a valid tautology, (2b) is false.[2]

(2) a. $p \wedge (q \vee r) \equiv (p \wedge q) \vee (p \wedge r)$

b. $p \wedge (q \vee r) \equiv ((p \wedge q) \vee p) \wedge r$

"p and q or r is equivalent to p and q or p and r."

The difference in meaning is a reflex of the structural difference in bracketing, and how it interacts with the composition of meaning. Just as the composition meaning of the expressions reflects their internal structure, so does its prosody. Prosody disambiguates spoken renditions of (2a) and (2b) and encodes the syntactic grouping by using prosodic boundaries of different relative strength.

As will be discussed in detail in this paper, constituents that syntactically and semantically group together are separated by weaker boundaries compared to constituents that do not group together. I will indicate prosodic boundaries with the pipe symbol '| '. The strength of a boundary can be conceived of as a rank of the boundary on a discrete strength scale of boundary strengths. The boundary rank is encoded in the number of pipes ('| ', '|| ', '||| '...). The intuitions about the prosody of the structures above can be represented as follows:[3]

(3) a. $p \mid \wedge\, q \mid\mid \vee p \mid \wedge\, r$

b. $p \mid \wedge\, q \mid\mid \vee p \mid\mid\mid \wedge\;\; r$

The first part of this paper, sections 2 through 4, investigates the fragment of English that only consists of proper names and the connectors *and* and *or*. Three findings are presented: (i) Semantics: prosodic phrasing closely reflects interpretive properties of an expression; all and only structures that are not *associative* employ prosodic boundaries of different strengths; (ii) Syntax: there are exactly Super-Catalan-many bracketings over a string of n elements, more than a purely representational theory with binary branching trees is able to represent; either a representational theory with n-ary branching trees or a cyclic theory have the correct combinatorial properties. (iii) Prosody: the syntax-prosody mapping fixes the *relative rank* of prosodic boundaries, but not the exact *type* of the boundary (e.g. intonational phrase vs. intermediate phrase). The syntax-phonology mapping only determines relative ranks. The generalization about which constituents are separated by the strongest boundary is recursive in nature, and cannot be captured without recursive reference to the syntactic structure, e.g., they cannot be captured by 'edge-based' theories of syntax-phonology mapping.

[2]The expression *((p and q) or p)* seems redundant since logically it is equivalent to p alone. But in natural language, disjuncts can be interpreted exhaustively, so the expression can mean ((p and q) or just p), and hence is perfectly well-formed. The possibility of an exhaustive reading of disjunction is observed in Hurford (1974) who discusses inclusive and exclusive uses of *or*.

[3]In this paper, I will not address the strength of the boundary between the connector and the following coordinate. The boundary ranks reported in this paper are based on native speakers' intuitions, but experimental results are reported in Wagner (2005b), Wagner et al. (2006), Wagner and Gibson (2006).

The results about the semantics, the syntax, and the phonology of coordinate structures can be captured by a cyclic algorithm that assigns metrical representations to expressions. Section 5 presents such a a mapping algorithm that is based on three simple assumptions: (i) syntax is binary branching and cyclic; (ii) syntactic cycles have to obey a semantic interface condition: they have to be semantically associative; (iii) each cycle is mapped to a prosodic domain, i.e. a foot on a new grid line in the relational grid. The prosodic representation of a complex expression is then built up by recursively combining the prosodies of its parts, in tandem with composing their denotation. This proposal contributes to recent evidence for a derivational mapping from syntax to prosody (Adger, 2001, Wagner, 2002, Arregi, 2002, Marvin, 2002, Dobashi, 2003, Kahnemuyipour, 2003, 2004, Legate, 2001, Ishihara, 2003, Wagner, 2005c,a, Adger, to appear, Kratzer and Selkirk, 2007), although the proposal differs in the exact assumptions made about what constitutes a cycle, how it is mapped to prosody, and also in that the main source of evidence discussed here comes from boundary strength and not prominence.

The final section 6 presents evidence that the presented system generalizes beyond the coordinate fragment. Two apparent mismatches between syntax and prosody that have been used to motivate the edge-based approach to syntax-prosody mapping: One involves structures that are prosodically flat but syntactically articulated, and the other involves true mismatches which are epitomized by the famous *cat that chased the rat that stole the cheese* (Chomsky, 1965, Chomsky and Halle, 1968). Closer inspection, however, reveals that the syntax might actually be quite in tune with prosody in both cases, and just as would be predicted based on the prosody assuming the syntax-prosody-mapping proposed here. This provides strong evidence favor of the approach pursued here and against alternative theories based on edge-marking, since they would effectively allow to derive the right prosody based on the wrong syntax.

2 Semantics: Prosody and Associativity

Utterances consisting only of proper names and connectors occur frequently as fragment answers to questions:

(4) Who went to the forest?
  a. Lysander and Hermia.
  b. Lysander or Hermia.

The fragment answer (4a) can be seen as a shorthand for (1a). Fragment answers are often analyzed as being derived from full sentences by IP-ellipsis (Merchant, 2003), so (4a) would be derived from (1). [4]

(5) a. Lysander and Hermia went to the forest.

[4] Some theories even derive conjunction by ellipsis of identical material in the first coordinate. This type of coordination reduction was argued for e.g. in Chomsky (1957, 36) andHarris (1957, 318ff)). Predicates requiring plural subjects are one of many problems for this approach:

(1) a. Lysander and Hermia gathered in the forest.
  b. * Lysander gathered in the forest and Hermia gathered in the forest.

See Schein (1997) for a recent discussion of coordination reduction and related analyses.

b. Lysander went to the forest and Hermia went to the forest.

The precise bracketing in coordinate structures often does not seem to affect the truth conditions of an expression, e.g. the following expressions are truth-conditionally equivalent despite of their different prosodic groupings:

(6) Who went to the forest?

a. Lysander | and Demetrius | and Hermia.

b. Lysander | and Demetrius || and Hermia.

c. Lysander || and Demetrius | and Hermia.

In the following, I will refer to the prosody in (6a) as ‘prosodically flat’. It is ‘flat’ in that the coordinates are separated by boundaries of equal rank and are thus prosodically on par; structures involving elements that are separated by boundaries of different strength I will call ‘ prosodically articulated’, e.g. (6b,c).

How do we perceive expressions with an articulated prosody? Constituents separated by relatively weaker boundaries are perceived as grouping together:

(7) a. A || or B | and C *Interpreted as: A or (B and C)*

b. A | or B || and C *Interpreted as: (A or B) and C*

Prosody reflects the attachment of constituents in the phrase marker. Based on observations from attachment ambiguities, Watson and Gibson (2004) hypothesize that “listeners prefer not to attach an incoming word to a lexical head that is immediately followed by an intonational boundary”, a hypothesis they dub *Anti-Attachment*. The data discussed here suggests a more general hypothesis:

(8) Hypothesis about Attachment and Prosody:
In a sequence $A \prec B \prec C$, if the boundary separating A and B is weaker than the one separating B and C, then [[AB] C], if it is is stronger, then [A [BC]].

Prosodic boundary strength reflects syntactic bracketing. There are apparent counterexamples to the hypothesis (8), to which we will return in section 6. Let’s consider now under what circumstances flat and articulated prosodies are used respectively.

2.1 The Associativity Hypothesis

Consider an analogy to the orthographic convention on placing parentheses in logical notation. Formulas (9a,b) are well-formed as they are, while formula (9c) is incomplete:

(9) a. $A \vee B \vee C$

b. $A \wedge B \wedge C$

c. $A \vee B \wedge C$

Parentheses are redundant in (9a,b) since disjunction and conjunction are associative operations; but structures in which the connectives *and* and *or* are used alternately, as in (9c), are not associative, and the bracketing is crucial to disambiguate one of two truth-conditionally distinct structures.

We can define a notion of associativity of expressions in natural language as follows: A constituent consisting of three elements x, y, and z is associative if its denotation does not change under either order of composition:[5]

(10) ASSOCIATIVITY
Elements x, y and z are associative if the following holds:
$[[x(yz)]] = [[(xy)z]]$

I propose the following hypothesis:

(11) ASSOCIATIVITY HYPOTHESIS

a. If a string of $n > 2$ elements are prosodically on par, then they are associative.

b. If a string of $n > 2$ is associative, they are prosodically a par.

The proposal is that prosodic boundaries are used parsimoniously and only distinguish boundaries of different strength when bracketing is relevant for interpretative reasons. If true, this would mean that prosody directly reflects the interpretative properties of an expression. Associativity as a factor in the structure of multiple coordinations has also recently been discussed in Winter (2006). The following two subsections present empirical evidence for the two parts of the associativity hypothesis (11a) and (11b) respectively.

2.2 Flat Structures are Associative

The first part of the associativity hypothesis (11a) conjectures that prosodically flat structures have to be associative, i.e. whenever the bracketing affects the truth conditions of an utterance an articulated prosody is obligatory.

Adverbs such as *together*, *alone* and *respectively* interact with other elements in an expression in ways that affect truth conditions. Consider the example (12). The context makes it clear that two apples were given out. The answer involves three people, so there must be a sub-grouping, depending on who had to share an apple. The answer in (12a) seems inappropriate, while (12b) and (12c) differ in their truth conditions:

(12) Two apples were given out, but I don't know to who. Who was given an apple?

a. # Lysander | and Demetrius | and Hermia respectively.

b. Lysander | and Demetrius || and Hermia respectively.

c. Lysander || and Demetrius | and Hermia respectively.

The bracketing is crucial and hence a flat prosody is prohibited, as predicted. The use of *respectively* is crucial. *Respectively* indicates that the distribution of the apples will be specified. Without the adverb, it would be possible to use a flat prosody and leave the exact subgrouping unspecified. The resulting meaning would be much weaker, equivalent to the interpretation resulting from replacing the coordinate structure with a plural description referring to the entire group as a whole. As expected, a plural description would also be inappropriate in this context:

[5]The parentheses '(...)' stand for functional application, as defined in Heim and Kratzer (1998). Sequences more elements are similary associative if the denotation does not change under any bracketing of these elements.

(13) Two apples were given out, but I don't know to who. Who was given an apple?
The three were given an apple respectively.

Consider also the case of *together*. The answer in the following dialogue is ambiguous: *Together* can take low scope, in which case Lysander went on his own, separate from Demetrius and Hermia; but it can also take wide scope, such that all went together as a group, and Demetrius and Hermia are furthermore marked as a sub-group, maybe because they are a couple:

(14) Who went to the forest?
Lysander || and Demetrius | and Hermia together.

Considering the low-scope meaning, we find that as expected based on the Associativity Hypothesis, it is impossible to encode this meaning using the 'flat' prosody or the prosody that places a strong boundary between Demetrius and Hermia but a weak boundary between Lysander and Demetrius:

(15) Who went to the forrest?
a. # Lysander | (and) Demetrius | and Hermia together.
b. # Lysander | and Demetrius || and Hermia together.
(assuming Lysander went on his own, and Demetrius and Hermia went together)

Other sentential adverbs in coordinate structures also interact with prosodic grouping:

(16) Who went to the forest?
a. Lysander || and probably Demetrius || and Hermia.
b. Lysander || and probably Demetrius | and Hermia.

In example (16a), only Demetrius' going to the forest is uncertain, whereas in (16b) the whereabouts of both Demetrius and Hermia are uncertain. When 'probably' takes scope over a single coordinate, then the coordinates can be separated by boundaries of equal rank, as in (16a); but when 'probably' takes scope over the two last coordinates, these two are grouped together and separated from the first coordinate with a stronger boundary (16b). Again, in this case changing the bracketing is not innocuous and results in different truth conditions, and as expected prosodic articulation is required.

The adverb 'both' has a similar effect (Lasersohn, 1995, 151). 'Both' introduces the presupposition that the expression in its complement refers to a group with exactly two members. In a structure with three elements, two must group together. Now consider:

(17) a. Both Lysander | and Demetrius || and Hermia.
b. Both Lysander || and Demetrius | and Hermia.

The flat prosody cannot be used with more than two coordinates:

(18) * Both Lysander, | [and] Demetrius, | and Hermia.

The interaction of 'both' with prosodic bracketing can be made sense of if (17a,b) involve a coordination distributing over two propositions, one of which includes a plural subject consisting of the two coordinates that are grouped together more closely. The bracketing is crucial and has a truth-conditional effect.

More evidence comes from predicates which interact with collective readings of DPs. Consider the following example (cf. Winter (2001, 31), also Schein (1993). Similar examples are also dicussed in Lasersohn (1995)):

(19) a. Lysander and Demetrius weigh exactly 200 lbs.

b. Lysander weighs exactly 200 lbs and Demetrius weighs exactly 200 lbs.

Sentence (19a) has a collective reading that (19b) lacks, which is that Lysander and Demetrius together weigh 200 lbs. Both sentences have a 'distributive reading', in which Lysander and Demetrius each weigh 200 lbs. In cases that involve a coordination with a collective interpretation the bracketing of coordinate structures can play a crucial role.

(20) Who weighs exactly 200 lbs.?

a. Lysander | [and] Demetrius | and Hermia.

b. Lysander | and Demetrius || and Hermia.

c. Lysander || and Demetrius | and Hermia.

Each sentence has a distributive reading in which each of the three weighs exactly 200 lbs. Example (20b) has an additional reading, where Lysander and Demetrius together weigh exactly 200 lbs and Hermia does so alone. This collective reading that groups Lysander and Demetrius together is absent in (20a) and (20c), which in turn has a reading in which Demetrius and Hermia together weigh exactly 200 lbs and Lysander weighs this much alone.

The findings reported here speak against against a theory of coordination which always reduces to set union, as defended most recently in Schwarzschild (1997). For Schwarzschild (1997), expressing grouping in coordinate structures is just one of many ways to pragmatically convey a salient 'cover' of a set of individuals. Schwarzschild (1999) discusses examples such as the following from Hoeksema (1983) (I added the prosodic annotation):

(21) Blücher | and Wellington || and Napoleon fought against each other near Waterloo.

It is not necessary to make the subset of individuals into a constituent. The following sentences are compatible with what happened as well (21):

(22) a. The generals fought against each other near Waterloo.

b. Blücher, Wellington and Napoleon fought against each other near Waterloo, (but I don't know who sided with whom).

But these sentences express a weaker proposition, merely that there was some fighting going on in which the three generals participated on at least two different sides. It is impossible to give the following sentence the reading intended in (21) (Lasersohn, 1995, 152):

(23) Blücher || and Wellington | and Napoleon fought against each other near Waterloo.

Furthermore, cases in which prosodic grouping is obligatory, such as the examples involving predicates such as *both* or predicates such as *weigh exactly 200 lbs* indicate that a more articulated grouping can form a necessary part the linguistic representation of an expression.

Finally, another way to induce truth conditional effects induced by bracketing is to alternate *and* and *or*. With alternating functors it seems that only the two prosodically articulated bracketings are possible. This observation was also made in Min (1996):

(24) a. # Lysander | and Helena | or Demetrius.
b. Lysander | and Helena || or Demetrius.
c. Lysander || and Helena | or Demetrius.

While in the earlier examples, it was adverbs or predicates that interacted with the bracketing to yield truth conditional effects, in the example in (24) it is the scope of *and* and *or* with respect to each other that is at stake. Again, as expected, prosodic bracketing is obligatory when it matters, lending further support to the first condition of the associativity hypothesis (11a).

2.3 Are all Associative Structures Prosodically Flat?

The second half of the Associativity Hypothesis (11b) states that all assocative structures are prosodically flat. Consider again the following dialogue with three alternative answers:

(4) Who went to the forest?
a. Lysander | and Demetrius | and Hermia.
b. Lysander | and Demetrius || and Hermia.
c. Lysander || and Demetrius | and Hermia.

The two answers in (4b,c) seem to justify the inference on the side of the listener that the speaker has some motivation for grouping two of the three individuals together—maybe because they went to the forest together, because they are a couple, or because they were grouped together in the context for some other reason. For instance, in the following context *Demetrius and Hermia* contrasts with *Helena* in the previous utterance:[6]

(25) Lysander and Helena?
No. Lysander || and Demetrius| and Hermia.

If prosodic articulation always licenses an inference about grouping this would suggest that truly associative structures must be prosodically flat, and any apparently unlicensed prosodic boundary licenses some covert structure that results in additional grouping and hence non-associativity.

However, it is not obvious that there could not be other factors involved. For example, introducing further sub-grouping might make processing a coordinate structure with many coordinates easier. Whether the grammar simply allows for additional optional brackets or whether spurious prosodic brackets are always interpreted as intended grouping (or maybe perceived infelicitous or a disfluency) is a question that needs to be investigated experimentally.

[6] It is also possible in this context to use the flat prosody in the answer, and contrast *Lysander, Demetrius, and Helena* as a whole with *Lysander and Hermia*.

This section argued for a close relation between the prosody of coordinate structures and their interpretative properties. Prosodically flat structure are semantically associative, prosodically articulated structures are non-associative. The prosody used in non-associative structures relates directly to perceived grouping. How does prosodic grouping relate to syntax?

3 Syntax: Prosody and the Combinatorics of Bracketing

A first step in trying to understand the syntax of the coordinate fragment grammar is to establish how many different bracketings are possible. The number and types of bracketings syntax provides is by no means uncontroversial. Culicover and Jackendoff (2005) recently argued that in the absence of evidence to the contrary, syntactic structures should be assumed to be 'flat' for simplicity reasons. According to Culicover and Jackendoff (2005), positing an articulated binary branching analysis of the VP structure, for example, necessitates positing sub-constituents which cannot be motivated based on the tests they apply, but only as much structure should be assumed as is necessary. This goes against the prevalent view in the minimalist literature (Chomsky, 1995, et. seq.), which usually assumes that syntax only creates binary branching phrase markers, an assumption that is again based on a simplicity assumption, namely that the basic structure building operation 'Merge' always combines two elements.

The problem with arguments based on on simplicity is that different assumptions about what counts as 'simple' will lead to different conclusions. What are the empirical issues at stake? A close look at the combinatorics of coordinate structures and its interaction with prosody reveals that a purely representational grammar assuming only binary branching trees is simply not sufficient for combinatoric reasons. The combinatorial power needed is at least that corresponding to tree representations allowing for n-ary branching. However, there is more than one way to achieve this combinatorial power.

3.1 The Combinatorics of Coordination

Taking prosody into account, it seems that we have to distinguish at least three different bracketings for the case of n = 3 coordinates:[7]

[7] This is not to say that there are only three 'readings' of these coordinate structures. But all the strategies of forcing further bracketing discussed seemed to converge on one of these three prosodic options. The bracketing of the functors themselves is irrelevant and not used for syntactic disambiguation. There might be a contrast between cliticizing to the right or to the left, but this, as far as I can tell, does not correspond to a syntactic/semantic distinction:

(1) a. Lysander and Hermia.
    b. Lysander'n Hermia.

In the following I will group the connectors with the following coordinates. There are several arguments in favor of this grouping. Ross observed the following contrast (Ross, 1967, 90–91):

(2) a. John left. And he didn't even say good-bye.
    b. * John left and. He didn't even say good-bye.

When a coordinate is extraposed, it is the second coordinate that extraposes, and the connector has to extrapose as well (15 Munn, 1993, , attributed to Gert Webelhuth):

(26) a. Lysander | and Helena | and Demetrius.

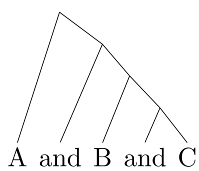
b. Lysander | and Helena || and Demetrius.

c. Lysander || and Helena | and Demetrius.

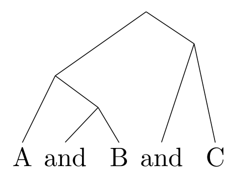
If all coordinate structures were binary, and if there are only binary branching trees, then it would be unexpected that there are *three* different syntactic structures with 3 coordinates. There are only two binary branching trees that one can construct for three elements under these assumptions:

(27) Two Binary Branching Trees, Assuming Binary Functors

a. Right-Branching



b. Left-Branching



The combinatorial question of how many binary branching trees there are over n linearly ordered elements is known as 'Catalan's Problem'.[8] The number of binary branching trees over n linearly ordered items is the Catalan number of (n-1). If coordination is always binary and attaches to the right, then the coordinators can be ignored in assessing the number of possible coordination with n coordinates. The Catalan number for n = 3 is 2. The recurrence relation for the Catalan number is given below:

(28) Catalan number
Catalan Number of (n-1) is the number of binary branching trees over n linearly ordered items.

$C_{n+1} = \frac{2(2n+1)}{n+2} C_n$

Catalan Sequence: for n = 1, 2, 3, 4, 5..., C_n is 1 1 2 5 14 ...

While the Catalan number of n = 3 equals 2, the number of bracketings in coordinate structures is (at least) 3, as was shown above.[9]

Church and Patil (1982) show that this number of bracketings is the one generated by a phrase structure rule that assumes each step of coordination to be binary:

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(3) a. John bought a book yesterday, and a newspaper.

b. * John bought a newspaper yesterday a book and.

c. * John bought a newspaper and yesterday, a book.

Since the connectors always group with the coordinate following them, we can ignore them for our purposes when we count the syntactic bracketings of coordintes in coordination structures.

[8] Named after the Belgian mathematician Eugène Charles Catalan (1814-1894). For references to proofs to the solution to Catalan's problem see Sloane and Plouffe (1995) or Sloane's archive of integer sequences at http://www.research.att.com/ñjas/sequences/Seis.html. The Catalan sequence is Sloane's A000108.

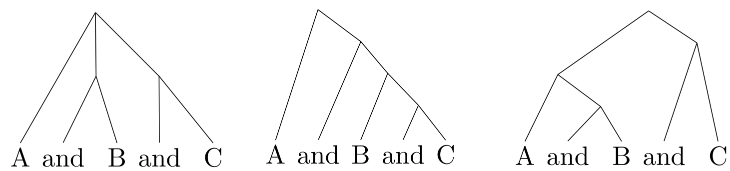
[9] Geoff Pullum claims in a language log post that there are 3 bracketings for 3 nominals: "This corresponds to the fact there are three bracketings for lifestyle consultation center: [lifestyle consultation center], [[lifestyle consultation] center], and [lifestyle [consultation center]]". http://itre.cis.upenn.edu/ myl/languagelog/archives/000160.html. Thanks to Chris Potts for pointing this out to me.

(29) $A \rightarrow A\ Co\ A$

One way to get to the right number of structures is to abandon the assumption of binary branchingness:

(30) Trees with Unbounded Branching

a. Flat b. Right-Branching c. Left-Branching



This is combinatorically equivalent to positing phrase structure rules that allow any number of arguments (Chomsky and Schützenberger (1963)):[10]

(31) $A \rightarrow A\ Co\ A\ (CoA)*$,
where $(Co\ A)*$ stands in for zero or more occurrences of $Co\ A$

The number of bracketings for n coordinates is then the number of trees over linear strings allowing arbitrary branching. This number is called the Super-Catalan number of n (see Stanley (1997) for discussion and references to proofs).[11]

These numbers are also called 'little Schröder numbers' and 'Plutarch numbers'.[12] The recurrence function looks as follows:

(32) Super-Catalan Number
Super Catalan Number of n is the number of unbounded branching trees over n linearly ordered items.

$$S_n = \frac{3(2n-3)S_{n-1}(n-3)S_{n-2}}{n}$$

Super-Catalan Sequence: For n = 1, 2, 3, 4, 5..., S_n is 1 1 3 11 45...

The possible bracketings of coordinations with n = 3 and n = 4 are summarized schematically below:

[10] See also Gazdar et al. (1985).

[11] The Super-Catalan Sequence is Sloane's A001003.

[12] Stanley (1997) gives an introduction into the combinatorics of this sequence and the history of its discovery, from which the following information is distilled:

Plutarch (ca. 50 A. D.–120 A. D.) was a Greek biographer. In his *Moralia*, Plutarch states the following: "Chrysippus says that the number of compound propositions that can be made from only ten simple propositions exceeds a million. (Hipparchus, to be sure, refuted this by showing that on the affirmative side there are 103049 compound statements, and on the negative side 310952.)"

103049 is the Super-Catalan of 10, and is the number of bracketings for n=10 coordinates. If we only combine propositions, as Plutarch suggests, then the associative law would render bracketing irrelevant in cases where we iterate the same connector. If we allow ourselves the use of both *and/or*, then the number of complex statements is of course 2*103049, since for each bracketing with *and* at the top level (of which there are Super-Catalan-many) there is one with *or* at the top level, so under this interpretation Hipparchus would have been off by a factor of 2.

See Stanley (1997) for a discussion of the actually fairly recent discovery that Plutarch was not just throwing out some random digits, in 1994, and Habsieger et al. (1998) for an interpretation of Plutarch's second number.

Ernst Schröder (1841–1902) was the first mathematician to specify a generating function.

(33) a. n = 3
xxx, x(xx), (xx)x

b. n = 4
xxxx, xx(xx), x(xx)x, (xx)xx, x(xxx), (xxx)x, (xx)(xx), x(x(xx)), x((xx)x), ((xx)x)x, (x(xx))x

The Super-Catalan number for n = 4 is 11. The simplest structure is a simple coordination or disjunction of four elements. The example given here is a disjunction of four alternatives:

(34) Lysander | or Demetrius | or Hermia | or Helena.

Consider now the three structures with three alternatives, one of which is internally complex:

(35) a. Lysander || or Demetrius or || Hermia | and Helena.
b. Lysander || or Demetrius | and Hermia || or Helena.
c. Lysander | and Demetrius || or Hermia || or Helena.

There also three structures with two alternatives, one or two of which are internally complex:

(36) a. Lysander || or Demetrius | and Hermia | and Helena.
b. Lysander | and Demetrius | and Hermia || or Helena.
c. Lysander | and Demetrius || or Hermia | and Helena.

Finally, there are four structures which involve two alternatives. Just as in (36a,b), one of the two is internally complex. The difference with the structures in (36a,b) is that the complex structure involves another level of embedding:

(37) a. Lysander ||| or Demetrius || and Hermia | or Helena.
b. Lysander ||| or Demetrius | or Hermia || and Helena.
c. Lysander || and Demetrius | or Hermia ||| or Helena.
d. Lysander | or Demetrius || and Hermia ||| or Helena.

Structures with two levels of embedding are reported from corpora in Langendoen (1998, 240).

(38) Combine grapefruit with bananas, strawberries and bananas, bananas and melon balls, raspberries or strawberries and melon balls, seedless white grapes and melon balls, or pineapple cubes and orange slices. (From the APHB corpus).

Langendoen (1998, 243) claims that coordinate structures with n levels of embedding, with $n > 2$, are ungrammatical—this would mean that the depth of embedding of the structures in (37) is the maximal depth that natural language can generate—but he does not present any evidence in favor of this claim, apart from the intuition that a fully articulated right-branching structure involving only *or* sounds odd out of context, which is hardly surprising. In a production experiment discussed in Wagner (2005b), at least some speakers differentiated three levels of embedding.

Natural language coordinate structures have at least Super-Catalan-many bracketings. The combinatorics presented in this section imposes a minimum on the number of structures that the grammar should provide for coordinate structures. I will assume in the following that grammar provides exactly Super-Catalan many bracketings.

3.2 Binary Branching Revisited

'Flat' unstructured representations have sometimes been taken as the null hypothesis for coordinate structures, e.g. Miller and Chomsky (1963, 196) state: "Clearly, in the case of true coordination, by the very meaning of this term, no internal structure should be assigned at all within the sequence of coordinate items." N-ary branching trees were assumed in many subsequent generative approaches, e.g. Gleitman (1965).

However, there is a translation of flat trees into binary branching trees. The idea is to use the linear precedence relation in the flat branching nodes (e.g. A $\prec$ B $\prec$ C $\prec$ D) and convert it into a nested right-branching structure (i.a. [A [B [CD]] in this case). Each flat tree is assigned a unique binary branching tree in this way (cf. the discussion in Rogers, 2003).

The translation of flat trees into binary trees does not necessarily affect the way the composition of meaning proceeds. Semantically, a function that takes n elements can be 'Schönfinkelized' or 'curried' into separate unitary functions (cf. Heim and Kratzer, 1998), so there is no reason to suspect that a translation of a flat tree into a binary branching tree would require a different theory of semantic composition. Büring (2005, 40), in his definition of functional application for flat structures, composes flat VPs with two arguments by combining the predicate successively with its arguments one by one according to linear order. Function application and variable binding of flat structures in current semantic theories then simply mimic the compositionality of a binary-branching structure, Büring (2005) treats VPs as if they had a left-branching structure with respect to the order of composition.

By converting flat branching nodes into right-branching nodes we 'neutralize' the distinction between 'originally right-branching' and 'originally flat' nodes. The piece of information that is lost is that all sisters in a flat branching tree are dominated by the same node. This missing information can be added to the binary trees by introducing labels to the tree notation, and distinguishing two kinds of right-branching nodes.

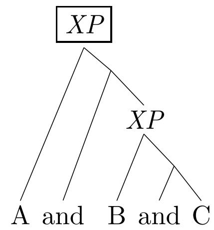
Marking certain nodes in the tree as special has a history. I$\bar{X}$-theory distinguishes 'XP-nodes' and intermediate $\bar{X}$ nodes (Jackendoff, 1977); alternatively, we might use the notion of 'shell'-structures from Larson (1988), and distinguish formerly flat structures from formerly articulated ones by giving them identical categorial labels; we might even incorporate the more general idea of 'extended projections', and try to distinguish the newly introduced right-branching nodes by looking at their categorial lexical labels (as opposed to their functional labels) following Grimshaw (2005); finally, another alternative to treat the special nodes as 'cycles' or 'phases' (Chomsky, 2001).

The choice of which kind of diacritic to pick will depend on the generalization about what types of structures are 'flat' structures. The generalization offered in the previous section was that whether or not a flat structure is used is a consequence of an *interpretative* property, associativity.

A property of the conversion is that formerly flat structures are always assigned right-branching nodes. Imagine that we would also allow new left-branching nodes. Then for n = 3, we would get too many different structures, e.g. for n = 3 we get 4 different structures instead of 3. In order avoid any theoretical bias, I will for now indicate the original nodes with a frame $\boxed{\text{XP}}$, and the newly introduced nodes without:

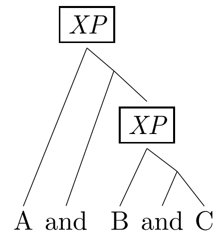
(39) Right-Branching

a. Flat prosody



'A and B and C'

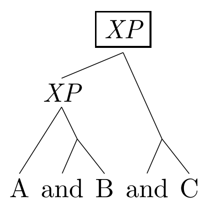
b. Hierarchical Prosody



'A and (B and C)'

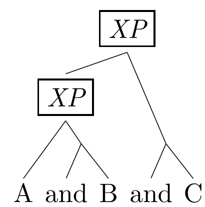
(40) Left-Branching

a. Flat Prosody
(Non-existant?)



?

b. 'Hierarchical Prosody



'(A and B) and C'

If we stipulate right-branching for the formerly flat nodes, labeled trees provide a combinatorial system consisting only of binary branching trees that map one-to-one to arbitrarily branching trees and thus a system that encodes Super-Catalan-many bracketings.

This might be well motivated. Haider (1993, 2000), following up on work by Larson (1988) on English VP-Shells, conjectures that right-branchingness is a systematic property of all extended projections:[13]

(41) Branchingness Conjecture (Haider, 2000)
For any two nodes *directly* attached to the *same* (extended) projection line, the node that precedes c-commands the node that follows.

There are then two isomorphic ways to achieve the correct combinatorial power:

(42) Two ways get Super-Catalan-many structures

a. Unbounded Branching trees.

b. XP vs. $\boxed{\text{XP}}$ distinction + Right-Branchingness Stipulation

The two theories are notational variants of each other, at least with respect to the number of phrase markers they provide for a tree with n terminal nodes. The important lesson to learn from the combinatorics of coordination is that whichever of the two options in (42) we employ, we should pick *exactly one* of them, since otherwise the combinatorial possibilities explode.

One reason why some researchers argued for a right-branching analysis of prosodically 'flat' coordinate structure is that, syntactically, there is an

[13]At least two syntactic approaches have in some way or other built into the system a preference of right-branching over left-branching structures: Kayne (1994) and Haider (1993). A detailed consideration of coordinate structures within those two systems would go beyond the scope of this paper.

asymmetry between the coordinates. One source of evidence for the asymmetry is variable binding. Consider semantic binding first (Munn, 1993, 16):

(43) a. Everyone$_i$ and his$_i$ goat was at the party.

b. * His$_i$ goat and everyone$_i$ was at the party.

Semantic binding is possible from the first coordinate into the second but not vice-versa.[14] There is a clear asymmetry in coordination structures. But what is the exact generalization about when semantic binding is possible?

Based on the examples so far, it could be that in coordination structures, linear precedence is sufficient for variable binding and for inducing condition-C effects. But more has to be said:[15]

(44) a. Every student$_i$ and (his$_i$ parents or his$_i$ adviser) have to be at the graduation.

b. * (Every student$_i$ and his$_i$ parents) or his$_i$ adviser have to be at the graduation.

This sentence does not have the reading indicated by the brackets in (b), in which it would be sufficient if all the advisers would show up, but no student. It seems that it is impossible to bind a variable from a more embedded coordinate into a coordinate of the next higher coordination or disjunction.

The left-right asymmetry persists even when the second connector takes scope over the first connector:

(45) * (His$_i$ adviser and his$_i$ parents) or every student$_i$ have to be at the graduation.

There is a simple generalization that captures the data—at least if we assume the binary right-branching representation of 'flat' coordinations:[16]

[14] Progovac (2003) argues that variable binding is licensed not by surface c-command but at LF after raising out the quantifier. The following example illustrates that this view is too simplistic:

(1) a. Every student$_i$, his$_i$ adviser, and the dean are invited to the reception.

b. * His$_i$ adviser, every student$_i$, and the dean are invited to the reception.

The movement necessary out of the conjunction in (1) example would violate Ruys' generalization about movement out of conjunctions. The following examples illustrate further complications in the data pattern:

(2) a. ? The dean, every student$_i$, and his$_i$ adviser are invited to the reception

b. * Every student$_i$, the dean, and his$_i$ adviser are invited to the reception.

Maybe Schein (2001)'s proposal that variable binding in coordinate structures involves 'telescoping' can account for these judgments.

[15] It is not clear whether (a) involves genuine variable binding or involve e-type variables. Negative quantifiers could rule out an e-type reading, and it seems that they lead to ungrammaticality, at least with an articulated structure. The contrast between (44a,b) has to be accounted for in any case, and it suggests a distinctions in terms of c-command.

[16] This is the definition of c-command used in Adger (2003a, 117). It is close to the standard definition of c-command, at least assuming bare phrase structure Chomsky (1994); Reinhart (1976, 23) proposed a more elaborate definition, in part due to the possibility of intermediate projections.

(46) C-command (cf. Adger, 2003a)
A node A c-commands a node B, if and only if A's sister either

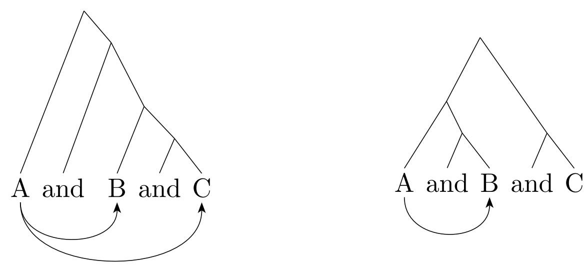
a. is B

b. or contains B.

This correctly distinguishes left- and right-branching structures. Consider the following tree representations. All c-command relations between the coordinates A, B, and C are represented by arrows:

(47) Left- *vs.* Right-Branching and C-Command

a. Right-Branching b. Left-Branching



A c-commands C in the right-branching but not in the left-branching structure. In the binary-branching approach, even the coordination structures with a 'flat' prosody would have a right-branching tree. The structure in (44b) is ungrammatical because 'every student' does not c-command the variable. It is further embedded in a left-branch and the variable is not within the sister of the quantifier phrase.

Of course, the entire node (A and B) in the left-branching structure c-commands C, and consequently it can bind a variable within C:

(48) (Every student or visitor)$_i$ and his$_i$ parents are invited.

The important point is that A and B themselves do not c-command constituent C. Variable binding thus constitutes evidence that right-branching structures and structures that have a 'flat' prosody actually have similar c-command properties, which is precisely why current syntactic theories of coordination often assume right-branching (e.g. Munn, 1993, 2000).

4 Phonology: Relative Boundary Ranks

The discussion so far has been based on intuitions about the relative strength of prosodic boundaries. The prosodic boundaries reported were not labeled with respect to the intonational categories (intonational phrase, phonological phrase, etc.) as they are standardly assumed in prosodic phonology (Selkirk, 1986, Nespor and Vogel, 1986, Truckenbrodt, 1995) and in the ToBI labeling convention (). What kinds of prosodic boundaries are used in coordinate structures? More generally, what kinds of syntactic objects are separated by what kinds of prosodic junctures?

Theories of syntax-phonology mapping often directly relate certain syntactic types of constituents to certain prosodic constituents. Selkirk (1986) e.g. proposes that there are certain designated syntactic constituents that end up providing the edges of prosodic domains with a certain label. This notion of designated syntactic categories for prosodic domains was expressed in Selkirk (1996, 444): as follows:

(49) The edge-based theory of the syntax-prosody interface
Right/Left edge of $\alpha \rightarrow$ edge of β,
α is a syntactic category, β is a prosodic category.

The particular list of prosodic domains and how they are 'syntactically grounded', i.e. which syntactic nodes correspond to them, was updated in Selkirk (to appeara), but the claim that the edges of certain syntactic syntactic constituents align with the edges of particular prosodic constituents persists in many current accounts.

The section presents evidence that points to a different notion of interface between syntax and phonology, one that does not fix the prosodic category, but rather only provides relative boundary ranks between prosodic constituents, which are then in turn implemented with the means the phonology provides.

4.1 A Recursive Generalization

The prosodic hierarchies provides a notion of boundary strength. Phonological domains lower on the hierarchy are separated by boundaries that are weaker compared to boundaries of domains higher on the hierarchy. Different researchers have made slightly different assumptions about the precise inventory of categories. For illustration, consider the hierarchy proposed in Selkirk (1986):

For illustration, let's consider some examples. The likelihood of an IP boundary, i.e. a prosodic boundary that is accompanied by boundary tones and substantial phrase final lengthening in a flat coordinate structure with three elements as the one in (50) is not very high. A typical rendition of (50 does not involve intonational boundaries between the coordinates:

(50) Lysander | and Hermia | and Demetrius.

Consider now what happens when we replace the last coordinates with a disjunction:

(51) Lysander || and Hermia || and (Demetrius | or Helena)

The presence of a weaker boundary within the third cooridnate, *Demetrius or Helena*, makes it more likely that a IP will separate *Lysander* and *and Hermia*. Conversely, the fact that the boundary between *Demetrius* and *or Helena* must be weaker than the earlier boundaries makes it less likely that an IP will separate them.

The important point is that the syntactic status of the relation between the coordinates is always the same, either DP coordination or disjunction. The information that determines which types of phonological junctures are likely to be used resides in the relation of the coordinates to the overall structure.

This type of effect is completely unexpected in theories that operate with designated syntactic categories, (Selkirk, 1986, Chen, 1987, Hale and Selkrik, 1987, Selkirk, 1995, Truckenbrodt, 1995, 1999). Since each coordiante in a coordinate structure should be mapped to the same prosodic category (maybe by XP-alignment), they should all be mapped to the same designated category, maybe the phonological phrase, Φ. This theory runs into problems in capturing any effect of nesting. The predicted phrasing for *every* coordinate structure should be flat:

(52) * (Lysander)$_{\Phi}$ (and Hermia)$_{\Phi}$ (or Demetrius.)$_{\Phi}$

The hierarchical prosody that is actually observed constitutes 'XP-within-XP' effects. A hierarchical prosody is observed, although the elements are each of the *same* syntactic category, and hence should map to the same prosodic category.

Generalizations about prosody in coordinate structures make reference to relative strength between cojuncts. Consider the following constraint on the prosody of coordinate structures proposed in Taglicht (1998, 192):

(53) *Coordination Constraint (CC)*
For any coordinating node X, if any two daughter nodes of X are separated by an IP boundary, all the daughter nodes of X must be separated by IP boundaries.

This is what is expected if, as argued above, the coordinates of an associative coordinate structure are prosodically on par. The data suggests that the means of phonology are simply used to signal the relative ranks that the syntax-phonology interface provides.

In fact, there is some lee-way how to use those means. It is up to the speaker whether or not express any particular rank with a stronger or weaker boundary, as long as the relative strength is correct.

Some phonological criteria from sandhi alternations allow us to identify a prosodic domain, let's call it the phonological phrase (Φ). The segmental rules that pertain to the set of rules that apply in Φ can then be used to signal grouping—but they need do not give information about the precise syntactic status of the elements they contain.

This relative notion of using phonological means to signal grouping makes predictions that are quite different from theories operating with designated syntactic nodes for specific prosodic domains. To illustrate this, I will use the segmental rule of flapping in English.[17] Flapping can occur in coordinate structures:

(54) a caɾ or a ratˀ

The relational view predicts that two constituents A, B that are usually mapped to a single prosodic domain P_i should be able to phrase separately if we make sure that either A or B contains a prosodic break itself. This prosodic break is predicted by the present theory to be prosodically weaker compared to the one separating A and B. The need to implement this difference in boundary rank should enable the grammar to map A and B to separate domains:

(55) a catˀ or (a raɾ and a hatˀ.)

Conversely, If a rule does *not* apply between two constituents, it should be possible to still enable the rule to apply by further embedding the structure in such a way that the boundary separating the two constituents has to be relatively weaker compared to some yet higher boundary.

(56) a dog and (a caɾ or (a raɾ and a hatˀ.)

Similar predictions are made for glottalization and glottaling in British English (cf. Kahn, 1976, Gussenhoven, 1986):

(57) a. American English Flapping and Glottalization:
(a caɾ or a ratˀ) and a hatˀ. *vs.* a catˀ(and a raɾ or a hatˀ.)

[17]Thanks to Charles Reiss for suggesting this.

b. British English Glottaling:
(a cat or a raʔ) and a haʔ. *vs.* a caʔ(and a rat or a haʔ)

In the American English example flapping occurs between lower boundaries but not higher boundaries. In the British English example glottalization occurs before higher but not before lower boundaries. Prosodically conditioned processes can be used to encode prosodic ranks. The choice of the domains, however, is not rigidly determined by grammar. There is a possible rendition of (57a) in which flapping occurs in the entire utterance (cf. Nespor and Vogel, 1986).

The relational view is still able to capture some of the generalizations that were the motivation for the prosodic hierarchy. For example, if a rule applies within a domain P_i it necessarily occurs within all domains P_j, $j < i$. However, it assumes a greater flexibility with respect to how boundaries of a certain strength relate to syntactic nodes compared to theories that assume designated syntactic categories. This greater flexibility is indeed attested for rules such as flapping in English.

The two predictions of the relational rule can be summarized as follows: (i) when in a structure two constituents phrase together and form a single domain for some phonological rule that applies in ϕ, then by making one of them more complex and thus requiring a weaker boundary to be realized within this constituent they can be forced into separate phrases. Such effects are amply discussed in the literature, often under the heading 'branchingness', e.g. Zec and Inkelas (1990), Dresher (1994), Elordieta et al. (2003), Pak (2005), and Prieto (forthcoming). The second prediction is that (ii), when two constituents do not phrase together in a single phrase ϕ, then by increasing the speech rate and/or embedding it deeper into a structure such that the boundary between the two constituents must be realized as being weaker than some other boundary, the two phrases should be able to phrase together.

These predictions should equally apply to the prosodic phrasing of expressions other than coordinate structures. Consider the example of clauses, which the edge marking approach predicts to be mapped to intonational phrases. Indeed, two coordinated sentences can be separated by intonational phrase breaks, with a clear boundary tone and lengthening at the juncture:

(58) Lysander likes Helena or Hermia likes Demetrius.

The plausible prediction of the relational view is now that if we embed this structure further, we might not find an intonational phrase break but a weaker boundary:

(59) a. Lysander likes Demetrius and (Lysander likes Helena or Hermia likes Demetrius).

b. Lysander denied that either (Lysander likes Helena or Hermia likes Demetrius.)

The predictions of the relational view must eventually be tested in detail on the classic cases of sandhi discussed in the literature on prosodic phonology, e.g. data from Chi Mwi:ni (Kisseberth and Abasheikh, 1974, Selkirk, 1986), Ewe (Clements, 1978, Selkirk, 1986), or Xiamen Chinese (Chen, 1987, Selkirk, 1986). In order to compare theories, more evidence with different numbers of levels of embedding and phrasings at different speech rates would be needed than are available in the original papers.

The procedure how to determine the boundary strength after a given word in coordination structure and arguably more generally must take into account the entire syntactic structure. It can only be given recursively: the boundary must be as strong as any other boundary within the same associative domain, weaker than the boundaries separating constituents this associative domain is embedded in, and stronger than boundaries of elements that are further embedded.

4.2 Recursive Implementation?

The syntax-phonology interface provides relative ranks–but are all derived ranks actually encoded in the output, or are they only realized up to a certain depth? And in implementing the relative ranks, are different types of prosodic domains categorically distinguished, as assumed in the prosodic hierarchy, or are there gradient cues of ever stronger boundaries, as has been suggested for example in Ladd (1986, 1988), Kubozono (1989, 1992), Ladd (1996) and Dresher (1994)?

These are empirical questions that require experimental investigation. It is important to highlight that they are orthogonal to the question of whether the syntax-phonology mapping involves a recursive generalization or not. Suppose, for instance, that the strongest version of the prosodic hierarchy theory is correct, and there is only a small set of prosodic domains and there is no recursion such that one domain is embedded in a domain with the same label. In order to decide which coordinates to separate by the strongest prosodic break it would still be necessary to consider the overall structure and the recursive generalization about relative strength would still be equally necessary in order to figure out which phonological categories to use to separate which coordinates.

That said, there is some evidence that the implementation of prosodic structure is more relational than sometimes assumed. Some phonological distinctions that were used to pinpoint to categorical differences between prosodic constituents have actually turned out to be gradient once measurements instead of impressionistic judgments are considered. This suggests that they cannot be used as evidence for designated categories since, on the contrary, they quantitatively distinguish degrees of boundary strengths. For example., Esposito and Truckenbrodt (1998) reports that there at at least two degrees of lengthening involved in raddoppiamento sinttatico, a phonological rule in Florentine Italian that has played a big role in the shaping of theories on prosody—but crucially based on the assumption that it is a categorical test for a single type of prosodic domain, the phonological phrase.

Other types of phonological processes which had been used to motivate the designated category hypothesis have been shown to not to be tied to surface prosody at all, and be determined syntactically, e.g. Liaison/enchainement in French (Pak (2005)). (Chen (1987), Hsiao (2002)) already observed that the tone sandhi domains in Taiwanese don't quite correspond to surface prosody but can be broken up by prosodic phrasing induced by focus.

Phonetic studies have revealed a number of gradient phonetic cues to boundary strength. For example, domain-initial strengthening reflects relative boundary strength, such that stronger boundaries are associated with more domain initial strengthening. Fougeron and Keating (1997), Lavoie (2001), Cho (2002), Keating et al. (2003), Keating (to appear) discuss evidence for such cumulative effects. Further evidene on how the relative ranks are implemented using duration in on-line speech production was presented in Wagner et al. (2006), Wagner and Gibson (2006), and Wagner (2005b), investigating the type of coordinate structure discussed here. Evidence for a relational implementation of prosody was also found in perception studies. Clifton et al. (2002) report evidence that boundary strength is interpreted by listeners in relation to previously realized boundaries.

To be sure, there are other properties of prosodic phrasing that seem categorical, e.g. the presence/absence of boundary tones associated with a particular juncture. The degree to which prosodic implementation distinguishes boundaries of different ranks either categorically or quantitatively remains a question for future research.

Categorical distinctions are perfectly compatible with the finding of this paper that the mapping from syntax to phonology only fixes relative ranks. We can think of the phonological phrasing as an implementation of relative boundary ranks. The phonological means of a language are employed to signal the ranks provided by the interface. The representation of relative prosodic ranks is discussed in the following section.

4.3 Compositionality and the Metrical Grid

The relational view syntax-prosody mapping makes it possible to think of the building up of prosodic structure in a compositional way. The idea of is that the prosodies of bigger constituents are composed of and properly contain the prosodies of their parts. Under this view, the prosodic representation of (60a) is a proper subpart of the prosodic representation of (60b):

(60) a. (p and q) or p

b. $\underline{\text{((p and q) or p)}}$ and r

This is not to say that the substring underlined in (60b) is *phonetically* identical to (60a). The two structures are identical at a more abstract level, just as the [k]s in spoken renditions of *cup* and *cat* are not phonetically identical, but are usually assumed to share an identical piece of information in their representation, the featural representation of [k]. Surface phonetic differences in the realization come about as a result of how phonological structure is implemented. But how is prosody represented?

Although prosodic phrasing closely reflects syntax, it is not transparently encoded in the syntactic tree structures usually employed in generative syntax. Chomsky and Halle (1968) propose a phonological notation that in fact *does* represent something that one may be tempted to interpret as a repesentation of boundary strength. The syntactic representation is 'transcribed' by employing boundary symbols that acrue by applying subsequent cycles:

(61) Syntactic Transcription according to Chomsky and Halle (1968) (ignoring connectors)

a. $\#\#\#\ A\ \#\#\ \vee\ B\ \#\ \wedge C\ \#\#\#$ A or (B and C)

b. $\#\#\#\ A\ \#\ \vee\ B\ \#\#\ \wedge C\ \#\#\#$ (A or B) and C

Where are these boundary symbols placed exactly?

> Chomsky and Halle (1968, 13): "As a first approximattion to the problem of analysis into words, let us assume that each lexical category (e.g., noun, verb, adjective) and each category

that dominates a lexical category (e.g., sentence, noun phrase, verb phrase) automatically carries a boundary symbol # to the left and to the right of the string that belongs to it (i.e., that it dominates [...])."

Could we simply replace 'certain places' by the current notion of cycles/phases? We could then simply add a boundary marks enclosing the elements of each cyclic domain. But this won't quite derive the right boundary strength. Consider what happens if we simply enclose 'cycles' with boundary marks in a more elaborate structure:

(62) (A or B) and C and D $\rightarrow$ $\#\#\# A \# \vee B \#\# \wedge C \# \wedge D \#\#\#$

The boundary separating C and Dis too weak. The information that is not reflected in the boundary symbols is that the three items (A or B), C and D are prosodically on par. The theory has to be revised such that all elements within a cycle are prosodically on par. The problem is reminiscent of a problem in the assignment of nuclear stress, discussed in Halle and Vergnaud (1987), Arregi (2002), which was resolved using the 'stress equalization principle', which brought the metrical representations of two sister constituents to the same level befor applying the Nuclear Stress Rule. A solution to the equalization problem is to employ the metrical grid, and add a convention that assures that elements that are combined are brought on par before applying rules such as the nuclear stress rule.

The metrical grid reflects the timing structure of an utterance, and was originally proposed in analogy to musical notation in Liberman (1975) and further developed in in Libermann and Prince (1977), Prince (1983), Selkirk (1984) and other works. The metrical grid encodes both prominence and prosodic grouping by virtue of prominence marks. It was first conceived of in analogy to music notation (Prince, 1983, 20): "A time signature, such as 2/4, imposes a kind of implicit metric on the pulse train, distinguishing certain pulses as intrinsically stronger than others." This is illustrated in Prince (1983) as follows:

(63) Metrical Grid

|	♩	♩	|	♩	♩	|	♩	♩	|
	×			×			×		
	×	×		×	×		×	×	

There is a one-to-one mapping between the rhythmic patterns in music notation and the representation of the grid. A higher prominence in the grid representation corresponds to a separation into different rhythmic intervals, and perceptually the beats chunk up the stream of sounds into smaller units. Each level of grouping adds a level to the grid.

The grid marks in the relational grid effectively due double duty: they encode prominence and they encode prosodic grouping. However, it turns out that grouping, or 'prosodic phrasing', and prominence must be separated—although they interact and intuitions about prominence are affected by phrasing. But often prominence is shifted around due to information structure, and yet phrasing remains intact. In the following dialogue, the break between the two coordinates remains perceptible in the answer, despite of the fact that the domains after 'Demetrius' is pitch-suppressed:

(64) Who will get married?

a. (Egeus and Helena) | and (Lysander and Hermia)?

b. No! (Demetrius and Helena) | and (Lysander and Hermia).

It is necessary therefore to distinguish prosodic phrasing from metrical prominence, at least in natural language, and this is why the notation purely relying on grid marks in Prince (1983) is not sufficient. The particular notation employed in the following is one where the grid is futhermore annotated for 'foot' boundaries. I will adopt a version of the bracketed metrical grid introduced in Idsardi (cf. 1992), Halle and Idsardi (cf. 1995):

(65) Bracketed Metrical Grid

a. A or (B and C)

$$\begin{array}{cccccc} \times &) & \times & & \times &) \\ \times &) & \times &) & \times &) \\ & & & & & \\ A & & B & & C & \end{array}$$

b. (A or B) and C

$$\begin{array}{cccccc} \times & & \times &) & \times &) \\ \times &) & \times &) & \times &) \\ & & & & & \\ A & & B & & C & \end{array}$$

The notation is to be read as follows: The right parentheses demarcate feet at each level in the grid. all material to their left up until another bracket is encountered counts as a foot (Idsardi, 1992, Halle and Idsardi, 1995). Foot boundaries at higher boundaries necessarily correlate with foot boundary at lower grid lines. And a foot can contain multiple grid marks, i.e. feet are unheaded. This representation encodes boundary strength in a straightforward way: feet at higher grid lines have stronger boundaries. The boundary rank can now be read off as the height of the column of pipes.

(66) Boundary Rank
The rank of a prosodic boundary is the number of the highest grid line with a foot boundary.

The feet of the metrical grid are implemented using the tools of phonology. Let's consider again the example of flapping: The idea is that in implementing the relational grid, the theory allows us to *choose* a line i in the grid that counts as the Φ-line. Within each foot at this line (and by implication all lower feet contained in it) the phonological rules associated with Φ will apply, but it won't apply across foot boundaries at higher grid lines.

How does the grid encode the location of pitch accents in a structure? I will assume that the following generalization holds about the implementation of the metrical structure:

(67) Accent Placement
All and only top-line grid marks receive pitch accents. All other material is either unaccented or the accents are realized within a reduced pitch range.

In general, each coordinate in coordinate structures receives an accent, which is reflected in the notation here by projecting top line grid marks within each coordinate to the top line of the entire structure.

The version of the grid I employ here departs from earlier literature (Prince, 1983, Halle and Vergnaud, 1987, Idsardi, 1992) in an important way. It does not represent nuclear stress, i.e. it does not encode the syllable that is perceived by native speakers as the most prominent. In fact, in most of the generative literature starting with Chomsky et al. (1957), Chomsky and Halle (1968), the nuclear stress rule (NSR) identifies exactly one vowel as most prominent for every expression. I think this notion of nuclear stress is useful, but in fact the representation in (65) already singles out nuclear stresses by virtue of them being always *last within their foot.*

Newman (1946) and Truckenbrodt (1995) observe that in English, main prominence is perceived on the last accented element within a constituent.

(68) NEWMAN'S GENERALIZATION (Newman, 1946, 176)
"When no expressive accents disturb a sequence of heavy stresses, the last heavy stress in an intonational unit takes the nuclear heavy stress."

Newman (1946, 174) singles out a heavy stress as 'nuclear' if it 'acts as the nucleus of an intonational unit'. Within any intonational unit it is always the last heavy stress that counts as the nuclear stress. Newman (1946, 176) suggests that in coordinate structures ('enumerations') each coordinate receives a nuclear accent. The intuition that each coordinate is on par will be captured here by the fact that the boundaries that separate them are identical. I will define a notion nuclear stress as follows:

(69) NUCLEAR STRESS GENERALIZATION
Within each foot, nuclear stress is perceived on the last of those grid marks that project highest.

Just as the originally proposed grid in Liberman (1975), Libermann and Prince (1977), it encodes the major 'beats', but does not single one of them out as being the main stress by projecting it to a higher line than any other beat in the string.

The underlying assumption is that prominence is not a primitive of the theory but emerges in the task of asking prominence judgements. Since each coordinate projects to the top line, the examples so far are not a particularly interesting illustration of the metrical grid. In fact, the notation seems redundant, since we could just as well have used the following notation:

(70) Flat Notation

a. Right-Branching

×	))	×	)	×	))
A		B		C	

b. Left-Branching

×	)	×	))	×	))
A		B		C	

But under certain circumstances some coordinates do not receive an accent, e.g. if there is a contrast as in example (71):

(71) Was it Demetrius and Hermia?
No, Lysander and Hermia!

In a natural rendition of (71) the material following the first coordinate is deaccented or at least heavily pitch reduced. It is *prosodically subordinated.* It is this type of prosodic subordination which is responsible for cases in which nuclear stress does not fall on the final element in a phrase (see Wagner (2005b)). We can present prosodic subordination in the grid as follows:

(72) Subordination

×	)		
×	)	×	)
Lysander		Hermia	

The 'nuclear' stress now falls on the syllable with main stress in 'Lysander', since it is the last unsubordinated element, i.e. the last element that projects to the top line. An important property of subordination is that the prosodic phrasing in the subordinated domain is maintained.

Similarly, the grid notation of the response in (64)) looks as follows:

(73) Phrasing in Post-nuclear domain

×	)						
×	)	×	)	×		×	)
×	)	×	)	×	)	×	)
Demetrius		Helena		Lysander		Hermia	

Nuclear stress of the entire answer is perceived on the main stress of 'Demetrius', since this syllable is the last (and only) one that projects a grid mark to the top line. For the same reason, nuclear stress within the first coordinate ('Demetrius and Helena') is perceived on that syllable. The prosodic phrasing within the subordinated material is maintained; the break after 'Helena' is intuitively stronger than that after 'Lysander'. That post-nuclear phrasing still reflects differences in boundary rank was experimentally tested in Jaeger and Norcliffe (2005).

Apart from information structure, there are other factor that can induce prosodic subordination, e.g. Wagner (2005b) argues that the functor-argument relation plays a crucial role and functors are subordinated when they are followed by their an argument in complement position. I will not discuss the determinants of prosodic subordination in this paper. Having established a representation for the relative boundary ranks and prosodic structure provided by the syntax-phonology interface more generally, we can now try to synthesize the various results of the investigation so far.

5 A Cyclic Theory

The relational view of the syntax-phonology interface outlined in the previous section puts us in a position to tie together the semantic, syntactic and prosodic results in a parsimonious way. The basic idea is to build up prosodic structure compositionally, in tandem with composing the denotation of complex expressions.

5.1 The Combinatorics

The first step is to make a decision about the precise syntactic theory assumed. There is a derivational interpretation of the labels *XP vs.* $\boxed{XP}$ introduced above exploiting something that every generative theory of grammar assumes: the recursiveness of language. Imagine we strengthen the right-branching conjecture in the following way:

(74) Strong Right-Branching Conjecture
In a given work-space, grammar only generates right-branching structures.

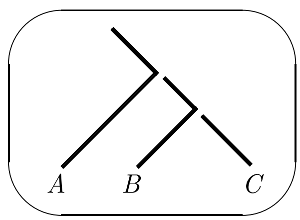
Every output of grammar is treated as an atom and can be fed into building an even larger expression, then even assuming (74) it is still to assemble a seemingly left-branching structures—just not within a single work-space.

(75) Recursion
Each output can re-enter a new work-space to build a yet bigger expression.

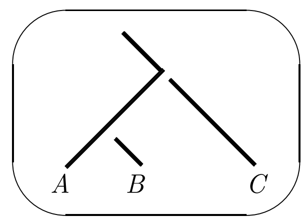
I will call work-spaces, that is the domain in which structures are assembled, a ‘cycle’ (equivalent: workspace/phase/level of embedding). Within any workspace, only (76a) can be generated, (76b) is impossible:

(76) Structure within a Cycle

a. Possible:



b. Impossible:



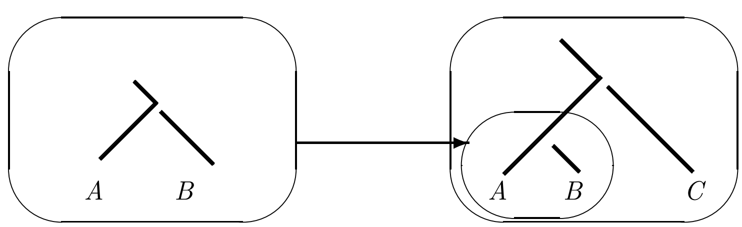
The right-branching assumption made here is similar to the principle ‘Branch Right’ proposed in Phillips (1996), which favors right-branching structures unless it is not compatible with the semantic interpretation of an expression. In the absence of a motivation for either a left- or right-branching bracketing, grammar imposes a right-branching analysis. A preference for right-branching structures is also at the heart of the asymmetric syntactic theories of syntax in Haider (1993), Kayne (1994). A derivational view of syntax is also argued for in Uriagareka (1999), Chomsky (2001), Johnson (2002).[18]

Deriving left-branching structures requires the combination of more than one work-space, while right-branching structures can be created in one go:

(77) Creating a Left-Branching Structure

a. First Cycle

b. Second Cycle:



This is the *only* way of deriving a left-branching structure. A right-branching structure might be derived either in one workspace, or in two steps. There are thus 3 ways of assembling structures with 3 elements. In fact, for n elements, there are exactly Super-Catalan of (n-1) many ways of building structure.

[18] Johnson (2002) in particular uses a notion ‘Re-numeration’, which is close to the way I will use the cycle, in order to explain adjunct island effects and also focus projection effects.

5.2 Associativity Condition on Cycles

We can now capture the interpretive properties of 'flat' coordination structure the following simple hypothesis: the elements combined in a single cycle must be semantically associative. As a result, the bracketing of the material within a cycle is immaterial. One motivation behind this organization of the grammar might be that associative structures form natural chunks of elements to process.

Associativity makes it immaterial wether the the structure within a cycle is built bottom-up (as is conventionally assumed) or top-down, with each step of Merge destroying earlier established constituent structure, as proposed in Phillips (1996, 2003).

There is some experimental evidence that a left-to-right, top-down generation is possible in prosodically 'flat' coordinate structures. Frazier et al. (2000, 360) report results from an experiment in which subjects were asked to read coordinate structures, varying the number of coordinates and whether or not all or only the last coordinator was pronounced.

(78) a. John and Fred.
  b. John, (and) Bill and Fred.
  c. John, (and) Bill, (and) Fred, and Harry.

There was no effect on reading time due to the number of coordinates (or the presence/absence of connectors). This suggests that in sentence production, material pertaining to a single cycle can be assembled from left to right by subsequently adding new constituents, rather than assembling the structure bottom up. Otherwise, one might expect the processing cost of the ever increasing number of upcoming constituents to affect the realization of the preceding constituents.

5.3 Deriving a Relational Grid

A metrical grid can be derived cyclically based on the following set of assumptions: Elements are combined throughout the cycle. When an associative domain is completed, the cycle is 'spelled out'. Part of 'spelling-out' is to map the content of a cycle to a single prosodic unit. I will call this creation of a prosodic out of two or more parts *Prosodic Matching*:

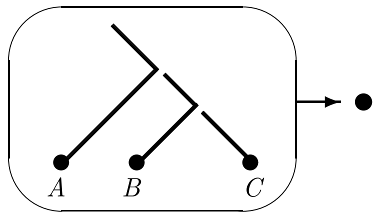
(79) Prosodic Matching
  a. Concatenate
  Concatenate the prosodic representation of the elements in the domain aligning their top lines and filling the columns where necessary.
  b. Project
  Create a new top-line grid line n by projecting all grid marks on line n-1, and mapping them into a single foot on line n.

In essence, this principle simply maps the output of the cycle to a single foot in metrical structure. 'Concatenate' plays a similar role in the present theory as the 'stress equalization principle' in Halle and Vergnaud (1987) and Arregi (2002). It assures that constituents that are combined in a cycle start out on an equal footing in their prosodic representation. A cyclic mapping of syntax to prosody was first proposed in Bresnan (1971), and has recently gained more currency in the context of 'phase'-theory (Chomsky, 2001), i.a. Marvin (2002), Arregi (2002), Adger (2003b), Dobashi (2003), Ishihara (2003), Kahnemuyipour (2003), Legate (2001), Wagner (2005c,a), Kahnemuyipour (2004) and Kratzer and Selkirk (2007).[19]

(80) Building a Right-Branching structure in one single cycle:

A | and B | and C

Spell-Out of the Cycle:



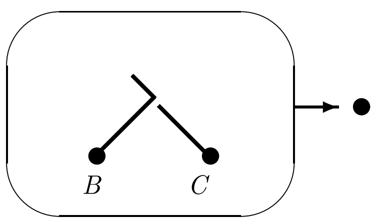
×		×		×	)
×	)	×	)	×	)
A		B		C	

A right-branching structure with three terminal nodes can also be derived in two separate cycles. This becomes necessary when the associative law does not hold, as in the following expression:

(81) A and (B or C)

One cycle combines the sub-constituent (B and C).

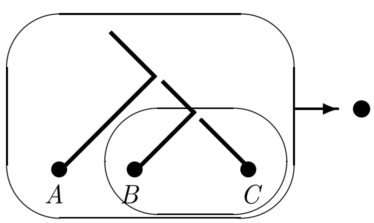
(82) First Cycle, Spelled-Out:



×		×	)
×	)	×	)
B		C	

The output of the first cycle is inserted into a second cycle:

(83) Spell-Out of the Second Cycle



When the second cycle is spelled out, the metrical elements corresponding to the elements in the cycle are concatenated. The grid representation of the concatenated grids looks as follows:

[19] Each coordinate in a coordination structure, I assume, has already undergone a cycle, and is thus spelled-out before in a separate cycle. Every elements thus come in with some metrical structure associated with them. I will not discuss the cyclic foot structure below the word in this paper. We can think of the cycle relevant for within-word phonology as syntactic cycles as well, as proposed e.g. in (Arad, 2005, Marantz, 2001, Marvin, 2002).

(84) Concatenating the Grids

×	)	×		×	)
		×	)	×	)
A		B		C	

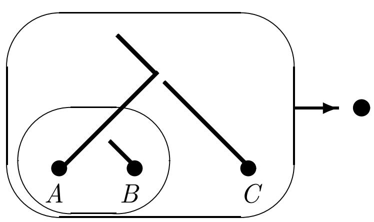
Then, a new grid line is projected. I will also ‘fill up’ the grid column that is unfilled, simply for notational reasons—the relations in the grid are relative, and constituents of different complexity can be matched to the same grid level.

(85) Spell-Out of Second Cycle

×		×		×	)
×	)	×		×	)
×	)	×	)	×	)
A		B		C	

Two different grids are derived, although representationally the same right-branching binary tree is involved. The grid keeps track of the derivational difference. A left-branching structure necessarily is created via two cycles, as observed above. The grid that is derived looks as follows:

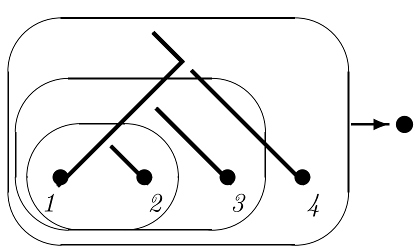
(86) Left-Branching Structure



×		×		×	)
×		×	)	×	)
×	)	×	)	×	)
A		B		C	

Three different grid structures are derived for the three different derivations. Similarly for the case of n=4, the metrical grid distinguishes 11 different derivations for the 5 different binary trees. Consider first a fully left-branching tree, which necessarily goes through 3 cycles:

(87) Left-Branching: 1 Derivation



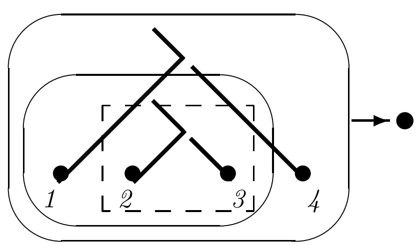
((Morgan or Joey) and Norman) or Ronny

×		×		×		×	)
×		×		×	)	×	)
×		×	)	×	)	×	)
×	)	×	)	×	)	×	)
A		B		C		D	

There are three binary branching tree involving 4 elements that have 1 right-branching node and one left-branching node. The elements on the right branch of a right-branching node can be either a separate cycle or be assembled together with the other material in the tree—which one is the right output depends on whether or not the associative law holds; the elements under the left branch on a left-branching node necessarily form a cycle together.

In the tree below, it is the first three elements that are on the left branch, and thus always form a separate cycle. Elements 2 and 3 may or may not form an additional separate cycle (a node that could be a separate cycle or be part of a bigger cycle, i.e. a right-branching node, is marked by the dotted rectangle, which reflects the fact there could be an extra cycle—depending on the content of the terminal nodes and whether or not the associative law holds within the cycle that contains it):

(88) One Right-Branching node: 2 Derivations



i. (Morgan and Joey and Norman) or Ronny

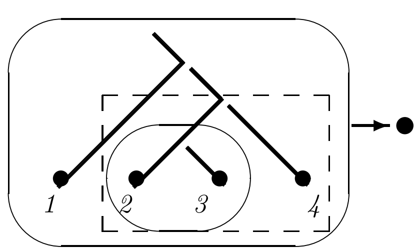
×		×		×		×	)
×		×		×	)	×	)
×	)	×	)	×	)	×	)
A		B		C		D	

ii. (Morgan and (Joey or Norman)) or Ronny

×		×		×		×	)
×		×		×	)	×	)
×	)	×		×	)	×	)
×	)	×	)	×	)	×	)
A		B		C		D	

In the second structure, the middle two elements are on the left branch of the left-branching node and thus form a cycle. The last three structures may or may not form another separate cycle:

(89) One Right-Branching node: 2 Derivations



i. Morgan or (Joey and Norman) or Ronny

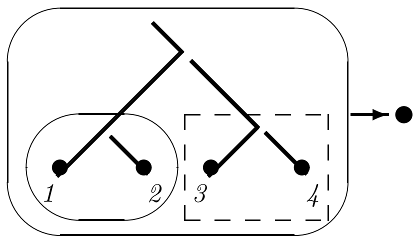
×		×		×		×	)
×	)	×		×	)	×	)
×	)	×	)	×	)	×	)
A		B		C		D	

ii. Morgan or ((Joey or Norman) and Ronny)

×		×		×		×	)
×	)	×		×		×	)
×	)	×		×	)	×	)
×	)	×	)	×	)	×	)
A		B		C		D	

In the following tree structure, the first two elements are on the left branch of a left-branching node, and the last two elements can form an additional cycle:

(90) One Right-Branching node: 2 Derivations



i. (Morgan and Joey) or Norman or Ronny

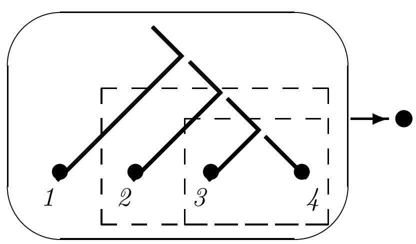
×		×		×		×	)
×		×	)	×	)	×	)
×	)	×	)	×	)	×	)
A		B		C		D	

ii. (Morgan and Joey) or (Norman and Ronny)

×		×		×		×	)
×		×	)	×		×	)
×	)	×	)	×	)	×	)
A		B		C		D	

Finally, the fully right-branching tree corresponds to 4 derivations, since each right branching node may or may not contain a separate cycle.

(91) Two right-branching nodes, 2 x 2 = 4 derivations



i. Morgan or Joey or Norman or Ronny

×		×		×		×	)
×	)	×	)	×	)	×	)
A		B		C		D	

ii. Morgan or Joey or (Norman and Ronny)

×		×		×		×	)
×	)	×	)	×		×	)
×	)	×	)	×	)	×	)
A		B		C		D	

iii. Morgan or (Joey and Norman and Ronny)

×		×		×		×	)
×	)	×		×		×	)
×	)	×	)	×	)	×	)
A		B		C		D	

iv. Morgan or (Joey and (Norman or Ronny))

×		×		×		×	)
×	)	×		×		×	)
×	)	×	)	×		×	)
×	)	×	)	×	)	×	)
A		B		C		D	

The cyclic approach derives representations that reflect speakers' intuitions about grouping in coordinate structures. There are 11 different derivations, and correspondingly there are 11 different grids. The only mapping principle necessary is the one that the domain of a spell-out is mapped to a new foot in the grid (79). The grid comes about as a result of the way syntactic derivations interact with this mapping principle. The metrical representation reflects not just the tree structure, but also how it was assembled. The close relation to semantics is a result of the associativity condition on cycles.

The presented system ties together the semantic, syntactic and phonological properties of the fragment grammar together in a parsimonious way.

The cyclic algorithm captures the recursive nature of the generalization about boundary strength. I have not given an argument that the derivational view is empirically superior to a representational view. One type of evidence could come from *cyclic* effects in prosody, i.e. generalizations that can be explained by letting certain grammatical constraints apply throughout the derivation, where later cycles render generalizations at earlier cycles opaque. This discussion would go beyond the scope of this paper, and the present algorithm should be seen as one out of a family of conceivable recursive approaches to the syntax-phonology interface.

There alternative interpretations of the proposed algorithm. One could view the tree structures that are composed in one single cycle as 'elementary trees', and the insertion into a new cycle as the operation of 'substitution' familar from tree adjoining grammar (Frank, 2002). There is nothing in the approach here that would decide between these different interpretations and for all I know they are equivalent. Note, however, that in order to obtain the right combinatoric power it would be necessary to restrict elementary trees to be either right-branching.

The question that I want to turn to now is whether the generalizations established for the coordinate fragment generalize to other domains.

6 Beyond Coordinate Structures

The discussion so far has been based entirely on evidence from coordinate structures. One way to test whether the model can be extended to other types of structures is to look at apparent counterexamples. In the following I will look at two types of mismatch: one involves structures that are prosodically flat but seem to be syntactically articulated; the other involves involves apparent bracketing contradictions between prosodic and syntactic structures.

6.1 VP Modifiers

Prosody is often not as articulated as the syntactic structures underlying an expression would suggest. For example, VP-final adverbials modifying the meaning of entire sentences (Taglicht, 1984, 67) receive a 'flat' prosodic realization in that the adverbials are separated by boundaries of equal strength:

(92) She saw him once,| in 1939, | outside the Albert Hall, | after a concert.

One common analysis of VP-adverbials is that they take scope over the VP material preceding them, leading to a 'right-ascending' structure (cf. Andrews (1983), Ernst (2001)). Their prosody, however, is not what we would expect in a left branching structure:

(93) ?? She saw him once, | in 1939, || outside the Albert Hall, ||| after a concert.

In fact, the prosody of such VP-modifier sequences is more similar to flat coordinate structures:

(94) A, B, C, and D.

Why do these structures have similar prosodies? Larson (2005) argues that VP-adverbials are not scope taking adverbials but are in fact event predicates that are tied to a single event by existential closure:

(95) a. kissed Hermia in the forest for an hour.

b. $\exists$ e [kiss(L, H, e) & in-the-forest(e) & for-an-hour (e)].

If this analysis is correct, then the bracketing between adverbials is semantically irrelevant. Sequences of event predicates form *associative* domains. They form lists of modifiers, and can be analyzed as coordinate structures, as was originally suggested in Taglicht (1984, 67).

The claim that the bracketing does not matter in sequences of event predicates does not mean that their *order* is free. In fact, word order in coordinate structures is not free either. The following coordinate structures are ordered based on chronology, scalar strength, and set-subset relations respectively, and random permutations would seem more marked:

(96) a. open Monday, Tuesday and Friday.

b. big, bigger, biggest.

c. Friends, Romans, countrymen, lend me...

There are more similarities between 'flat' coordinate structures and sequences of VP-adverbials. Just as would be expected from associative domains assembled in one cycle, they are in fact syntactically right-branching (cf. Larson, 1988, Pesetsky, 1995, Phillips, 1996). One piece of evidence comes from NPI-licensing:

(97) a. Lysander kissed nobody in any forest at any time.

b. John spoke rarely during any of our meetings. (Larson, 2005)

More evidence comes from variable binding:

(98) a. Sue spoke to every child on his or her birthday.

b. John spoke during every session for as long as it lasted.

Another kind of modifier can be analyzed analogously to VP-final adverbials: depictive predicates. Consider first subject-oriented secondary depictive predicates. They are prosodically similar to VP-Adverbs in that they do not induce strong prosodic boundaries in a sequence of predicates, and in that the order can vary.

(99) Hermia was dancing, completely drunk, without any fear, unaware of the abyss.

Pylkkänen (2002, 27) observes that depictive predicates share semantic properties with VP-Adverbs. Similar to VP-adverbs, the state described by a depictive predicate must hold during the event described by the verb, i.e. they can be seen as predicates that attribute a property to an event. That secondary predicates indeed have to be eventive, Pylkkänen argues, is evidenced by the fact that individual-level predicates sound odd in depictive predications (as observed in Geuder (2000)):

(100) *? Hermia was dancing tall.

In Pylkkänen's analysis, depictives differ from VP-adverbs only in that in addition to the event argument, they also have an unsaturated individual argument of type *e*. The event argument, just as in the case of VP-adverbs, is bound by existential closure; the e-type individual variable is bound by a c-commanding nominal argument.

If secondary predicates form a list structure with the VP and form an associative domain, just as VP-adverbs do, then a right-branching right-descending structure is expected. Indeed, subject-oriented secondary predicates are c-commanded by the direct object, as is evidenced by variable binding, suggesting that they are indeed put together with the preceding VP by the default right-branching structure expected in a cycle:

(101) The teacher rewarded every child convinced of her worthiness.

Under this analysis, the structure of the VP can be assumed to essentially that of coordination of predicates, which contain argument variables that are bound by c-commanding elements.

If the analysis of secondary predicates assumed here is correct, then an additional prediction is made for their prosody. Prosody should not disambiguate between whether or not a secondary predicate is subject- or object-oriented, since both are event predicates that differ only in the index on the individual variable they contain.

Consider the following sentence, mentioned in a footnote in Lehiste (1973):[20]

(102) The patient left the operating room in good condition.

The more salient interpretation of (102) is surely that the patient was left in good condition. In a context with an exceptionally rowdy patient, however, the reading in which it is the operating room that is reported to be left in good condition might be the intended one. Since in both cases the secondary predicate 'in good condition' is an event predicate that conjoins with 'left the operating room', the prosody should be the same for the two readings.

6.2 Additional Arguments

Another case in which several items seem to be prosodically on par are sentences that include many arguments. Sentences can contain a variety of nominal arguments, each with a different thematic role. Some of them are arguments of the main verb of the sentence, others are introduced by other heads; they are 'additional' arguments that are not part of the argument list of the main predicate. Consider the following sentence:

(103) Lysander baked a cake for Hermia.

Many theories treat the direct object as an argument of the verb, and the benefactive argument as being introduced by a different functional head. Part of the reason for making this difference is the intuition that a benefactive can be added to just about any sentence that involves an agent, while the thematic role of the direct object here is closely tied to the meaning of a verb of creation such as 'bake'. Another reason for treating the benefactive as different is the fact that it is an optional argument.

The status of the subject in (103) is more controversial. Some theories of argument structure treat agents just like the direct object as an argument

[20] Lehiste mentions this sentence to illustrate that if a particular reading is more likely in a context, prosodic disambiguation may be unnecessary. But consider a version of this sentence in which both attachments seem equally likely:

(1) The doctor left the patient in a good mood.

Again, the prediction is that prosody should not disambiguate between a subject- and an object-oriented reading of the secondary predicate.

of the verb (e.g. Bierwisch (1983), Grimshaw (1990)); but there are also theories that treat agentive subjects as being introduced by a separate functional head, analogous to the benefactive, even if they are clearly not necessarily optional.

One piece of evidence that subjects are indeed not arguments of the main predicate is that the thematic role of the subject is not fixed by the verb, but depends on the combination of the verb and the direct object it combines with (Marantz, 1984). Schein (1993) presents intricate semantic arguments for this view and argues that subjects are an argument of a separate event predicate. Additional evidence that agentive subjects are indeed introduced by a functional head other than the main predicate are discussed in Kratzer (1996) and Pylkkänen (2002).

In the event predicate analysis to argument structure (the 'Neo-Davidsonian' approach (Parsons, 1990)) there are as many event predicates as thematic roles, and they relate an event argument and an event argument. According to Kratzer (1996) and Pylkkänen (2002), agentive subjects are arguments of an inflectional *voice* head. Kratzer (forthcoming) presents crucial evidence that an analogous analysis of the theme argument is not warranted, and direct objects should be treated as proper arguments of the verb. The event predicates are either tied together by existential closure (Larson, 2005), by 'event identification' as in Kratzer (1996) or by predicate modification Heim and Kratzer (1998), Pylkkänen (2002).

The event predicates themselves can then just be added in a list structure. The meaning of (103) is the following:

(104) $\exists e.[voice(e)(Lysander)\ \&\ bake(e)(cake)\ \&\ BEN(e)(Hermia)]$

A property of this analysis is that the combination of the event predicates obeys the associative law, just as in any other coordination or list structure. Since their meaning is determined entirely by what their nominal and event argument are bound by, the bracketing within the list is not distinctive:

(105) [[(voice(e)(Lysander) & bake(e)(cake)) & BEN(e)(Hermia)]] = [[voice(e)(Lysander) & (bake(e)(cake) & BEN(e)(Hermia))]]

The expectation is then that the elements of the list of additional arguments should be set off by prosodic boundaries that are on a par. This is compatible with speakers' intuitions about the prosody of these structures, including the fact that the direct object is special and phrases together with the verb:

(106) Lysander | baked a cake | for Hermia.

If indeed the separate event predicates form an associative domain, then we would expect that they should form a right-branching structure. C-command evidence indeed shows that there is left-to-right c-command in sentences with several additional arguments:

(107) a. Every guest baked a cake for his host.
b. He reedited every movie for its main actor.

Pylkkänen (2002) also identifies a number of arguments that are *not* introduced by a predicate that relate an event and an individual. Instead, they are introduced by a head that directly relates two nominal arguments. A case in point are the two arguments in the double object construction in English, and low applicatives more generally. Prosodically, they are then predicted not to be on a par with the other arguments, but should form a domain of their own. I do not have the time and space to explore the prosody of ditransitives, but refer the reader to Seidl (2000) and Mcginnis (2002) for discussion of the prosody of different types of applicative constructions and observations that suggest that this prediction is correct.

6.3 Predicate Sequences

A last type of prosodically flat structure is exemplified by the sequences of predicates in the following sentence:

(108) She wanted | to try | to begin | to plan | to move.

The last predicate is always accented, and each of the other predicates can be accented in principle. In determining were exactly accents are placed rhythm plays a role. The prosody is very similar to that of list of predicates, in that the predicate sequence receives a 'flat' prosody, i.e. the boundaries between the predicates are perceived as being equal in strength, just as in an actual list:

(109) to want, | to try | , to begin, | to plan, | and to move.

Given the flat prosody, the expectation is that the domain is associative. But how can we interpret the predicates when the bracketing is changed? A simple way to think about how predicates can be interpreted given a different bracketing is to postulate lambda-abstraction:

(110) ($\lambda x.$ wanted to try to begin x) ([$_{VP}$ to plan to move]).

Lambda-abstraction turns a sequence of predicates, the lowest of which lacks its complement, into a one-place , and predicate abstractions turns it into a one-place predicate. The denotation of the final expression not changed by this restructuring, since the denotation of the moved VP semantically reconstructs to the complement position of 'begin' due to the λ-abstract. In other words, the law of association holds:

(111) $[\![\text{A(BC)}]\!] = [\![\text{(AB)C}]\!]$

An alternative view to the one involving variables and λ-abstraction is the one taken in categorial grammar. Steedman (1985, et. seq.) proposes that any sequence of predicates can be composed in more than one way. He uses the notion 'functional composition', an operation of meaning composition used in categorial grammar in addition to 'functional application'. In particular, Steedman uses a rule of forward function composition (Steedman (2001, 40), Steedman (2004)).

(112) Forward composition (simplified)
$X/Y : f \;\; Y/Z : g \Rightarrow X/Z : \lambda x.f(gx)$

Note that foward composition also does not alter the truth conditions of the outcome, i.e. , the associative law holds.

That substrings of predicates can be interpreted as one-place predicates can be motivated based on a number of grammatical phenomena. Consider first a simple case of coordination of predicates and their prosody relative to the argument(adapted from Mccawley, 1998, 275):

(113) a. Tom washed and dried || the dishes.

b. * Tom washed || and dried the dishes.

According to Mccawley, the only way to obtain a prosodic break behind the first predicate is to also put a break behind the second predicate:

(114) * Tom washed || and dried || the dishes.

This sugest that the boundary of the boundary following the coordinated predicates cannot be weaker than the boundary following the first predicate. The prosody of this sentence suggests then that the constituent 'the dishes' attaches outside of the coordinate structure 'wrote and defended'. The boundary preceding the direct object is stronger than the prosodic boundaries within the conjunction[21]

Now consider the following example, an instance of right-node raising, often analyzed as rightward movement in (Ross, 1967, Sabbagh, to appear):

(115) She wanted to begin | and then decided to postpone || her dissertation.

The prosody of this sentence suggests that the constituent 'her dissertation' attaches outside of the coordinate structure 'wanted to begin but then decided to postpone'. But this would imply that two apparent non-constituents are coordinated, namely 'wanted to begin' and 'then decided to postpone'. How can this kind of structure be interprted?

In order for the coordinate structure to be semantically interpretable, the predicates have to be assigned a meaning, despite the fact that in each coordinate the direct object is missing: they are turned into one-place predicates, either by virtue of λ-abtraction or forward composition.

The combination of function application and λ-abstraction has the effect that sequences of functors form associative domains. Just as in associative domains in coordinate structures, they receive a 'flat' prosody in which the elements are separated by prosodic boundaries of equal strength.[22]

[21] This is the case at least when the right-node raised constituent is accented. Hartmann (2001) observes cases were the right node constituent clearly is not preceded by a strong boundary. I assume that this is only the case when an unaccented constituent is right-node raised:

(1) a. John sáw | and Mary mét him

b. John had his glásses | and Mary had her lénses replaced

Hartmann (2001), Selkirk (2002), and Selkirk (to appearb) argue that even accented right-node raised constituents phrase with the material in the second coordinate. This, however, seems at odds with Mccawley's observation in (113). At any rate, the predictions of this view with respect to durational effects as their are induced by boundary strength clearly differ which suggests a direction future experimental work.

[22] A more problematic type of prosodically 'flat' expression are possessor sequences, which are evidently *left-branching*:

(1) John's brother's sister's dog's house.

Larson and Cho (1999), however, discusses evidence that this left-branching structure might not be the underlying one. Consider the following example:

(2) John's former house:

a. A former house that belongs to John (dispreferred).

b. A house that formerly belonged to John (preferred).

The left-branching structure gives the wrong bracketing. Larson and Cho (1999) argues that at the underlying level, the structure is right-branching, and then a reversal in word order between possessor and possessee takes place.

6.4 Relative Clauses

So far we discussed several cases of prosodically flat domains that turn out to be list-like in that they are semantically associative and right-branching just as coordinate structures. Their prosody is thus consistent with the approach developed for coordinate structures. Cycles are associative, and associative domains map to 'flat' prosodic domains.

Let's now turn to a different kind of mismatch, one in which the prosodic and syntactic bracketing stand in outright contradiction. Consider a structure that is syntactically right-branching: [A [BC]]. If the prosodic boundary separating A and B is weaker than that separating B and C, this would be a clear violation of the hypothesis of attachment and prosody, repeated below:

(8) Hypothesis about Attachment and Prosody:
In a sequence $A \prec B \prec C$, if the boundary separating A and B is weaker than the one separating B and C, then [[AB] C], if it is is stronger, then [A [BC]].

Restrictive relative clauses are often taken to be an instantiation of just such a bracketing mismatch (Chomsky (1965, 13), SPE, 372):[23]

(116) This is | the cat || that chased | the rat || that stole | the cheese.

The relative clause forms its own phonological domain and is separated from the head of the relative clause by a boundary that is stronger than the boundaries that in turn separates the head from the predicate that precedes it. According to SPE, the bracketing in syntax should be as follows:

(117) This is [the cat that chased [the rat that stole the cheese.]]

The solution proposed in Lieberman (1967, 120) and in SPE was that a readjustment rebrackets (117) into a different structure in which the three clauses are treated as on par: "The resulting structure appears then as a conjunction of elementary sentences (that is, sentences without embeddings). This allows us to say that intonation breaks precede every occurrence of the category S (sentence) in the surface structure, and that otherwise the ordinary rules prevail" (SPE, 372).

Subsequent approaches considered the 'readjustment' to be an effect of the mapping of syntactic structure to prosodic structure, which result in a mismatch (i.a. Nespor and Vogel, 1986, 57, 257). The boundaries separating the relative clause can e.g. be taken to be due to alignment constraints that force prosodic boundaries at the edge of certain syntactic constituents, in this case a clausal node. The different bracketing is then seen as a genuine mismatch between prosody and syntax.

It is conceivable though that the readjustment takes place *within* syntax The nature of readjustment was left open in SPE, and was considered a

(3) Movement analysis: the house to John →. John to.the house

A right-branching underlying structure is exactly what is expected if possessor sequences are formed in a single cycle. How exactly the reordering takes place when the cycle is linearized, and whether or not possessor sequences can plausibly be analyzed as semantically associative remain questions for future inquiry.

[23] Note that the relative clauses must be restrictive since non-restrictive relative clauses do not permit the relative pronoun 'that' (Mccawley, 1998, 445):

(1) ?? Mary, that John asked for help, thinks John is an idiot.

'performance' phenomenon, although this was not fleshed out in detail. In this section, I will give some arguments in favor of a syntactic approach—the main point that I want to make is that there is evidence for a *syntactic* bracketing that *matches* the prosody.

In a natural rendition of (117) the boundaries after the verbs are usually weaker than those preceding the relative clause. This is exemplified in (118a), which is the preferred phrasing compared to (118b):

(118) a. that chased | the rat || that stole the cheese.

b. that chased || the rat | that stole the cheese

The prosody in (118b) may be appropriate in a context that has narrow focus on the direct object, but is otherwise not be the preferred phrasing:

(119) Who did the cat chase?
The cat chased || the rat | that stole the cheese

The phrasing that corresponds to the syntactic bracketing that Aspects and SPE assumed is then possible, at least under certain circumstances, so any theory that automatically maps the syntax to a mismatching prosody is not desirable. In the familiar 'mother goose' nursery rhyme about 'the house that Jack built', the last line can be pronounced such that the head and last relative clause are not separated by a prosodic break as strong as ones ending the preceding lines, again suggesting that there are two different possible phrasings for restrictive relative clauses:

(120) This is the cat, ||
that killed the rat, ||
that ate the malt, ||
that lay in the house that Jack built.

But how can the apparently mismatching prosodic break preceding at least the first three relative pronouns be derived? The possibility discussed here is that extraposition is involved. Extraposition of restrictive relative clauses is certainly possible:

(121) I saw the cat yesterday that caught the rat on Monday that had stolen the cheese on Sunday.

String-vacuous extraposition would render a bracketing that corresponds to the surface bracketing posited in SPE for the problematic cases:

(122) [[This is the cat] [[that caught the rat] [[that stole the cheese]]]]

In order to test whether prosody really mirrors the syntax, it would be necessary to control whether or not extraposition takes place or not. Adverbs can be used to force extraposition as in (121), but how can we control for extraposition in the absence of overt intervening material?

Hulsey and Sauerland (2005) argue that extraposition is impossible if the head of the relative clause is an idiom chunk:[24]

(123) a. Mary praised the headway that John made.

[24]While I could replicate the contrast between these two examples here, there is not doubt that it is much less clearcut than reported in Hulsey and Sauerland (2005), and for other idioms with a less transparent meaning most speakers reject relativization altogether. I quote the example with the judgments reported there.

b. * Mary praised the headway last year that John made.

If extraposition is involved in rendering the prosody in (117), then we expect to see an effect of idiom chunks on prosody. Consider the following two constructions, with the prosody that groups the head with the following relative clause:

(124) a. This was entirely due || to the headway that she had made before.

b. This was entirely due || to the surplus that she had made before.

The prediction is now that the 'mismatching' prosody discussed in SPE should be impossible when the head of the relative clause is an idiom chunk. This is confirmed by impressionistic data collected from several native speakers, who sense a contrast in acceptability between the following two examples:[25]

(125) a. This was entirely due || to the headway that she had made before.

b. ?? This was entirely due to the headway || that that she had made before.

This contrast constitutes evidence for the claim that readjustment, the rebracketing observed in SPE and Aspects, requires syntactic extraposition, thus removing the case for an apparent bracketing paradox between syntax and prosody.[26]

A comparison with German supports the extraposition-analysis of the English data. The OV word order in embedded clauses has the effect that extraposition is easy to diagnose—it is not string-vacuous as in English. Consider the following example, similar to the one discussed in SPE:

[25] The judgment is reminiscent of cases with focus within idioms, which are infelicitous since there is no alternative for a focused material that would make sense as a replacement given the idiomatic interpretation of the structure:

(1) ?* She *KICKED* the bucket.

[26] There is another property that might distinguish different types of relative clauses. Restrictive relative clauses are often prosodically subordinated. This was observed i.a. in Bresnan (1971, 258):

(1) Mary liked the propósal that George left.

Nuclear stress falls on the head of the relative clause. But this, as was critically observed in Berman and Szamosi (1972) and Lakoff (1972), is not always the case. Bresnan (1972, 337) illustrates the problem with the following two examples due to Stockwell (1972):

(2) a. Introduce me to the man you were tálking about.

b. I'll lend you that bóok I was talking about.

According to Bresnan, there is also a semantic difference between the relative clauses: if the relative clause receives nuclear stress, then it is used to pick out one out of a set of alternatives defined by the head noun. In this case the head of the relative clause is a concealed partitive. In the sentence with nuclear stress on the head noun, however, there is no such partitive reading. A potential explanation for the intuition reported by Bresnan in the discussion of effects of information structure in Wagner (2005b). The prosodic contrast between subordinated and non-subordinated relative clauses was related to raising *vs.* matching derivations of relative clauses in unpublished work by Karlos Arregi.

(126) Ich glaube dass dies die Katze ist, die die Ratte gejagt hat,
I believe that this the cat is that the rat chased, that
die den Käse gestohlen hat.
the cheese stolen has

'I think this the cat that chased the rat that stole the cheese.'

The relative clauses are extraposed, as is obvious considering the word order. The head is separated from its relative clause by the predicate. Without extraposition of the relative clauses, the structure would be a center-embedded structure, and end up unintelligible:[27]

(127) ?* Ich glaube dass dies die Katze die die Ratte die den Käse gestohlen hat gejagt hat ist.

Similar to the case of English, extraposition is strange in German when the head of the relative clause is an idiom chunk.

(128) a. Peter war über den Bären den Maria ihm aufgebunden
Peter was about the bear that Maria him given
hatte verärgert.
had annoyed

'Peter was annoyed about the prank that Maria played on him.'

b. * Peter war über den Bären verärgert, den Maria ihm aufgebunden hatte.

The analysis of the 'extraposed' relative proposed in Hulsey and Sauerland (2005) is actually not one of literal extraposition, i.e. movement of the relative clause away from its head. Intead, they posit that the relative clause contains a silent operator, which is coindexed with and bound by the overt head of the relative clause. The relative clause is merged as an adjunct where it is pronounced.[28]

The interpretation of the relative clause is thus fixed entirely by the coindexation of the silent operator, and the precise location of the relative clause and the relative bracketing between several relative clauses does not directly affect their interpretation. The crucial constraint restricting the placement of this kind of relative clause in the syntactic structure is that the empty operator within the clause must be bound by the overt head—this makes it impossible e.g. for the relative clause to *precede* the constituent it restricts.

A sequence of relative clauses can then be seen as a list of modifiers, and since rebracketing between them does not affect the meaning we expect there to be a flat prosody between several relative clauses. This is in fact attested, both for nested and stacked relatives. The following sentence is ambiguous between a reading in which Mary had mentioned the cat or the rat:

[27]Center-embedding structures, used as an example for a performance restriction in Chomsky (1965), have been to shown to be hard to process in structures across languages and different constructions. The preference for extraposition of relative clauses may well have a motivation that relates to processing. This is in fact the explanation favored in SPE for the readjustment of relative clauses in (117). But the relevance of processing factors in the choice of construction does not mean that they are not syntactically distinct, and the syntactic and semantic effects of extraposition observed in Hulsey and Sauerland (2005) suggest that they are.

[28]This is based on the analysis of extraposition of adjuncts in terms of 'later merger' discussed in Fox and Nissenbaum (1999) and Fox (2002).

(129) This is the cat, that chased the rat, that Mary had mentioned.

The syntactic analyses matches up nicely with the prosody expected under the approach proposed in this paper. The prosody that was often taken to indicate a mismatch between syntax and prosody might actually be a reflex of ‘extraposition’, i.e. of a different syntactic construal that allows to adjoin the relative remotely and structurally removed from its head. It may well be that the reason that extraposed structures are sometimes preferred over non-extraposed structures because of parsability and ease of processing, and/or to pronounceablity, as discussed in SPE (p. 372) and also in Lieberman (1967, 120–121), but that does not imply that syntax is not involved.

6.5 Coordinate Extraposition

A crosslinguistically common pattern of prosodic phrasing is to group the first coordinate of a coordinate structure with a preceding predicate:

(130) (Predicate A) (and B)

Once again, this looks like a counterexample to the hypothesis on attachment and prosody (8). Although *A and B* apparently form a constituent to the exclusion of the predicate, the phrasing groups the predicat and the first coordinate together.
In Tiberian Hebrew (Dresher, 1994, 19), for example, fixed expressions, such as ‘good and evil’ in (131a), are phrased together, but otherwise, the predicate frequently phrases with the first coordinate (131b):

(131) a. (yōḏʕē) (ṭoḇ wārāʕ)
knowers (of)good and.evil (Gen. 3.5)

b. (kabbēḏ ˀet-ˀāḇīḵā) (wəˀeṯ-ˀimmeḵā)
Honor ACC-your.father and.ACC-your.mother (Deut. 5.16)

Phrasing in Tiberian Hebrew is reflected by spirantization (underlining) which applies to post-vocalic stops within a phonological phrase. According to Dresher, it is also directly encoded by the Masoretic system of accents. The same ‘mismatching’ prosody is possible in English:

(132) a. She kissed || Lysander | and Demetrius.

b. She kissed | Lysander || and Demetrius.

Are syntax and prosody really in a mismatch? The first step is to note that ‘extraposition’ is possible (Munn, 1993):

(133) John bought a book yesterday, and a newspaper.

But is extraposition always involved in the mismatching phrasing? How can we tell? A look at OV structures is instructive. Let’s consider intransitive predicates:

(134) a. A student attends, and one professor from another department.

b. * A student attend, and one professor from another department.

The obligatory first coordinate agreement observed in ‘extraposition’ structures suggests that what looks like movement of the second coordinate is probably gapping. If the second coordinate was really able to ‘move’ to the right, the agreement pattern would be the same as in-situ.

For VO structures, the prediction is now that prosody should correlate with first/second coordinate agreement; the judgments are very subtle though:

(135) a. In the seminar room there were/??was || a teacher | and two students.

b. In the seminar room there ??were/was | a teacher || and two students.

Another way to force the ‘extraposition’ structure is to employ the adverb ‘too’, and here the judgments are unambiguous. Consider first the OV-case:

(136) a. John has arrived, and Mary, too. So two people have arrived.

b. # John and Mary have arrived, too. So two people have arrived.

In the ‘extraposed’ case there must have been two events of arriving, in the non-extraposed case there can have been only one event of arriving. These interpretive properties again point toward an analysis in terms of gapping rather than literal extraposition.

A similar set of facts is expected now for the case of the direct object. This prediction is borne out:

(137) a. I saw John, || and Mary, too. So two people have arrived.

b. # I saw John | and Mary, || too. So two people have arrived.

Conversely, we can try to use the adverb *together* to prevent extraposition.

(138) a. John and Mary arrived together.

b. * John arrived, || and Mary together.

The facts are parallel in the case of VO structures:

(139) a. # I saw John, || and Mary, together.

b. I saw John | and Mary, || together.

The idea that what looks like a syntax-prosody mismatch is really due to a matching bracketing in syntax is further supported by restriction on phrasing in Tiberian Hebrew observed in Dresher (1994, 19).

(140) a. (kī-ḥemˀā ūḏḇaš) (yōḵēl)
for-curds and.honey shall.eat

b. * (kī-ḥemˀā) (ūḏḇaš yōḵēl)

The reason for this restriction proposed here is simply that there is no leftward ‘extraposition’. If the boundary following the first coordinate is stronger than the one preceding it, ‘extraposition’ (i.e. coordinating something bigger while gapping part of the matieral) has taken place.

The type of mismatch discussed here and in the previous discussion on relative clauses has been used in earlier literature to argue for the edge marking theory of prosody-syntax mapping (Chen, 1987, Selkirk, 1986, et seq.).

For the case of coordination in complement position, it is easy to derive a ‘mismatching’ phrasing from the basic syntactic bracketing:

(141) a. [saw [John$_{XP}$ [and Mary$_{XP}$]$_{\bar{X}}$]$_{XP}$.

b. (saw John)$_{\Phi}$ (and Mary)$_{\Phi}$.

In the examples discussed, both relative clauses the case of conjoined arguments, the mismatch turned out to be illusional, and thus the original motivation for edge-alignment is thus diffused.

More importantly, for the cases discussed here, the edge-marking approach would *wrongly permit to derive the right phrasing from the wrong syntax*. In other words, while the edge-marking theory is of course compatible with the correct syntactic analysis involving 'extraposition' (or rather: gapping), there is nothing that *forces* such an analysis, and the observed prosody should be equally compatible with the basic syntactic structure without gapping. The edge-marking approach fails to account for the generalization that in fact the tests that preclude extraposition render the 'mismatching' prosody ungrammatical and is thus untenable. The more restrictive theory that prohibits this type of mismatch makes the correct predictions for the syntactic analysis based on the prosodic facts.

There are other types of mismatches between prosody and syntax that would require more discussion, especially the cross-linguistically pervasive mismatches in the placement of certain heads and clitics that often underlie complex prosodic and grammatical restrictions, which in all likelihood can induce genuine mismatches. One type of example directly relates to coordinate structures: cross-linguistically, the connector in coordinate structure has a tendency to be placed within the second coordinate, and the generalization about where exactly it is placed seems to require reference to prosody (see Agbayani and Golston, to appear, for a recent discussion).

The goal here was to illustrate that the theory developed here based on coordinate structures works even for many cases that hitherto where taken to motivate a much more indirect mapping between syntax and prosody in terms of edge-marking, and that the more restrictive theory actually serves to make interesting and correct predictions about syntax.

7 Conclusion

The prosody of linguistic expressions, just as their semantic interpretation, reflects the recursiveness of language. Recursion was recently characterized as special to human language and as the crucial aspect of the human language faculty (Hauser et al., 2002), other disagree in the assessment that the only thing that is special about human language is recursion Pinker and Jackendoff (2005) or that the type of recursion observed in grouping is specific to language (Hunyadi, 2006) .

Whether or not recursion is shared by other components of cognition is beyond the scope of this work. However, recursion plays an important role in understanding the prosody of human language. The crucial claim is that prosody reflects syntactic constituent structure and also interpretive properties such as associativity.

The specific proposal was that prosodic phrasing can be derived from the way syntactic derivations work by the simple assumption that the output of cycles gets mapped to a foot in prosodic representations. The systematic relation between syntax, prosody, and semantics is captured by positing an interface constraint on cycles: cycles must be semantically associative.

Generalizations about prosodic phrasing were argued to be recursive in nature, and the strength of prosodic boundaries reflects the degree of embedding of sub-constituents in the syntactic structure by virtue of their *relative* ranks. The mapping of the relative boundary ranks to phonological categories is a matter of implementation, and depending on speech rate and the place of a phrase marker in bigger syntactic context there is substantial variation as to how exactly the relative ranks are realized. The question of how recursive phonological *representation* itself is is an empirical one and independent of the question of whether the interface mapping has to be stated in terms of recursive generalizations.

The prediction of the proposed theory is that prosodic boundary ranks reflect syntax in a much direct fashion than alternative theories. If so, instead of viewing the grid as a separate representation, completely independent of syntax, we can see it as *another way of representing syntactic information.* A similar view is developed in Steedman (2004). This is as expected according to the program for a metrical theory originally outlined in Liberman (1975, 258): "Thus the most basic assumptions of our theory depend on the idea that the phonological component is not so much a destruction of structure, which maps a complex tree onto a simple serial ordering of segments, as a transmutation of structure, which maps a structure suitable for operations in one domain (syntax and semantics) onto a structure suitable for use in another domain (the motor control of articulatory gestures, and its perceptual analogue)."

The measure of success for a theory of the syntax-phonology mapping is whether it turns syntactic facts into phonological facts and phonological facts into syntactic facts, in the following sense: the theory should be specific enough to make inferences about the syntactic structure by looking at its prosody, and conversely allow inferences about prosody by looking at the syntactic derivation. This is the standard of how to deal with facts about linear precedence, one of the main sources of evidence in syntactic research. Linear precedence itself is a phonological notion, and yet it can be used as evidence in syntactic argumentation. The reason is that there are explicit assumptions that allow inferences about syntactic constituency and hierarchical relations (e.g. c-command) based on linear precedence.[29]

In current research on syntax, prosodic structure does not have the same status as linear order as a source of evidence. Only occasionally are prosodic facts used in syntactic arguments. The reason is that the relation between syntax and prosody is less well understood, and inferences about syntax just based on prosodic evidence are often not possible since theories do not make predictions that are restrictive enough.

The paper is a step toward a more restrictive theory syntax-phonology mapping that allows for inferences about syntax based on prosody. Looking at the prosody under the assumption that the generalizations obtained for the coordinate fragment of English generalize to other domains generated interesting predictions for two apparent types of counter-examples. Closer inspection suggests that syntax might actually be quite in tune with what would be expected based on their prosody after all. This comes as a surprise for edge-based theories, which fail to make correct predictions for the actually observed syntax based on prosodic phrasing, and, even more troubesome, provide a way to derive the right phrasing from the wrong syntax.

[29] An example of a mapping theory is the LCA, in Kayne (1994) and subsequent work in the antisymmetric framework; other work on syntax–linear order include current versions of OT syntax (e.g. Sells, 2001), representation theory (Williams, 2003), or the theory of cyclic linearization in Fox and Pesetsky (2005), Ko (2005), Sabbagh (to appear), Takahashi (2005).

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