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PROSODIC RECURSION AND PSEUDO-CYCLICITY IN DANISH COMPOUND STØD*

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We analyze the contextually determined realization of Danish compound stød in terms of Match Theory with recursive prosodic words. The analysis makes predictions for long compounds, which a preliminary investigation has shown to be correct. We present a factorial typology where Danish is midway between languages with perfectly matching compound prosody, and languages that prosodically flatten underlying morphosyntactic structure. The analysis has consequences for the proper formulation of binarity constraints. While a binarity constraint counting branches yields the correct results for Danish, a binarity constraint counting leaves does not.

Keywords: Danish stød, compound prosody, Match Theory, binarity constraints

1 Introduction

Prosodic structure reflects syntactic structure, but only imperfectly. This imperfect correspondence finds a natural expression in the framework of Optimality Theory (Prince and Smolensky, 1993/2004), whether the correspondence is expressed as a requirement that the edges of prosodic constituents are aligned with syntactic constituents (Align/Wrap Theory: Truckenbrodt, 1995; 1999), or a requirement that prosodic and syntactic constituents match each other (Match Theory: Selkirk, 2011). Recent work on the syntax-prosody interface (e.g. Selkirk, 2011; Ito and Mester, 2013; Selkirk and Lee, 2015) argues for a limited crosslinguistic hierarchy of prosodic categories: the intonational phrase (ι), corresponding to the complementizer phrase (CP) in syntactic structure; the phonological phrase (φ), corresponding to other syntactic maximal projections (XPs); and the phonological word (ω), corresponding to the syntactic word (X^0).

Further distinctions between prosodic nodes, previously taken as evidence for a richer inventory of prosodic categories, have been subsumed under the rubric of prosodic recursion, where a node may dominate another node of the same prosodic category. Match Theory predicts that imperfect correspondence can occur at all levels of the prosodic hierarchy. However, most existing work focuses on the phonological phrase, to the neglect of the intonational phrase (an exception is Myrberg 2013) and phonological word (but see also Ito and Mester 2007 on Japanese). In this paper, we examine an instance of imperfect correspondence at the level of the (prosodic/syntactic) word, with a case study of Danish compound words, using the Danish glottal accent as the diagnostic for the prosodic word.

In Danish, words are lexically specified as able or unable to bear the glottal accent, known as *stød*. The host for stød must be a sonorous second mora (Basbøll, 2003; 2005). Ito and Mester (2015) argue that the distribution of stød is largely predictable on the basis of the word's prosodic

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shape: *stød* is favored by a culminativity constraint WORDACCENT, but disfavored when it is not in a word-final stressed syllable. Hence, the presence of *stød* indicates the right edge of the prosodic word, and its absence from an otherwise eligible syllable indicates a misalignment with the right edge of the word. This alignment requirement can be seen in compound words (Ito and Mester, 2015). In monosyllabic compound-initial words, *stød* (marked with a superscripted glottal stop) disappears (1), but in longer compound-initial words it is retained (2).

- (1) *Stød lost on short first word*
- | | | | | |
|----|--|---|--------------------------------|-------------------|
| a. | /ru: [?] g+brø: [?] d/ | → | [ru:g+brø: [?] d] | ‘rye bread’ |
| b. | /to: [?] g+passage: [?] r/ | → | [to:g+pasasge: [?] r] | ‘train passenger’ |
- (2) *Stød retained on long first word*
- | | | | | |
|----|--|---|--|---------------------|
| a. | /passage: [?] r+to: [?] g/ | → | [passage: [?] r+to: [?] g] | ‘passenger train’ |
| b. | /medici: [?] n+industri: [?] / | → | [medici: [?] n+industri: [?]] | ‘medicine industry’ |

As suggested by Ito and Mester (2015), the pattern in (1–2) can be accounted for if we admit prosodic recursion, and if short compound-initial words do not project their own prosodic word node. On this analysis, the syntactic compound word (e.g., [passage:[?]r + to:[?]g]) is always mapped to a matching prosodic word. Long compound members are also always mapped to a perfectly corresponding prosodic word. As a result, the final syllable of a long word like [passage:[?]r] always receives *stød*, because it is always final in a prosodic word. But short syntactic words do not receive their own prosodic word when embedded in compounds, so that a word like [to:[?]g] ‘train’ bears *stød* in isolation and when final in the compound, but loses *stød* when it is initial in the compound, as in [to:g + passage:[?]r] ‘train passenger’, since it is no longer aligned with the right edge of any prosodic word.

Stød in Danish compound words, then, provides an example of imperfect mapping at the level of the word. In the interest of better exploring the range of possible syntax-prosody mappings at the word level, we extend Ito and Mester’s (2015) analysis of *stød* to compounds like (1–2). We establish a ranking using Match Theory, which derives words of the appropriate prosodic shape by ranking a BINARITY constraint over NONRECURSIVITY, and NONRECURSIVITY over a MATCH constraint (Section 2). This ranking predicts that three-member compounds will be parsed pseudo-cyclically; the behavior of *stød* in a pilot experiment supports this prediction (Section 3). In Section 4, we show that the binarity constraint must count branches, rather than dominated feet (“leaves”) to derive the partial-matching effect seen here. Finally, we explore the predictions of the resulting Optimality–Theoretic analysis for the typology of compound word prosodies (Section 5).

2 Analysis of two-word compounds

To obtain the correct prosodic structure for each of the compound types in (1–2), we posit only three constraints, all of which are well-established in the syntax-prosody literature. (We abstract away from constraints on metrical parsing, on which see Ito and Mester (2015)).

- (3) BINMAX(ω ,Branches) (BINMAX-BR)
Assign a violation for every ω which immediately dominates more than 2 nodes.
- (4) NONRECURSIVITY (NONREC)
Assign a violation for every ω dominated by another ω .

- (5) MATCH(X^0, ω) (MATCH- X^0)
 Every syntactic word X^0 must be matched by a prosodic word ω .

We assume that right-headed compounds Y^0+X^0 have the form in (6a).

- (6) a. *Compound syntax* b. *Perfect match*
- $$\begin{array}{c}
 X^0 \\
 \diagup \quad \diagdown \\
 Y^0 \quad X^0
 \end{array}$$

$$\begin{array}{c}
 \omega^{\text{Max}} \\
 \diagup \quad \diagdown \\
 \omega^{\text{Min}} \quad \omega^{\text{Min}}
 \end{array}$$

Since MATCH(X^0, ω) favors a recursive word structure (6b), it comes into conflict with NON-RECURSIVITY in all compounds. The relation between a prosodic structure like (6b) and the realization of stød is based on the following proposal from Ito and Mester (2015):

- (7) *Stød Alignment* (Ito and Mester, 2015)
 A possible stød site is only realized with stød when it is final within some ω .

Crucially, (7) does not differentiate between ω^{Min} , ω^{Max} , or other levels of prosodic recursion. For an OT implementation of (7), see Ito and Mester (2015). Here, we simply take (7) as a diagnostic for the right edge of ω , rather than attempting to derive it.

A consequence of (7) is that a possible stød-bearing syllable will lack stød if it is not final within some ω . In a compound composed of two monosyllabic words, such as *ru:g+brø:ʔd* ‘rye bread’, stød is lost on the first word but retained on the second. This follows if *ru:g* does not project its own minimal ω , but is merely a foot contained within the maximal ω comprising the entire compound. (In the candidates below, the final word always keeps its stød due to its finality within the ω^{Max} , so whether it projects an ω^{Min} is irrelevant.)

- (8) *Tableau for Short-Short compound*

	BINMAX-BR	NONREC	MATCH
$ \begin{array}{c} N_2 \\ \diagup \quad \diagdown \\ N_1 \quad N_2 \\ (ru:g) \quad (brø:d) \end{array} $			
a. \rightarrow $ \begin{array}{c} \omega \\ \diagup \quad \diagdown \\ F \quad F \\ ru:g \quad brø:ʔd \end{array} $			**
b. $ \begin{array}{c} \omega \\ \diagup \quad \diagdown \\ \omega \quad F \\ \diagup \quad \diagdown \\ F \quad F \\ ru:g \quad brø:ʔd \end{array} $	e	*W	*L

c.	$ \begin{array}{c} \omega \\ \swarrow \quad \searrow \\ \omega \qquad \qquad \omega \\ \qquad \qquad \\ F \qquad \qquad F \\ ru:ʔg \quad brø:ʔd \end{array} $	e	*W	*L
d.	$ \begin{array}{c} \omega \\ \swarrow \quad \searrow \\ \omega \qquad \qquad \omega \\ \qquad \qquad \\ F \qquad \qquad F \\ ru:ʔg \quad brø:ʔd \end{array} $	e	**W	L

In (8a), placing each foot directly below ω^{Max} , with no intervening ω^{Min} s, results in a structure $[\omega \text{ FF}^{\text{?}}]$ which fully satisfies BINMAX-BR and NONREC. Candidates (b–d), which each contain at least one ω^{Min} or ω^{Max} , fare worse than (a) according to NONREC, but better according to MATCH. We therefore obtain an Elementary Ranking Condition (ERC) establishing the partial ranking $\text{NONREC} \gg \text{BINMAX-BR}$ (Prince, 2002; Brasoveanu and Prince, 2011).

A nearly identical scenario ensues for S+L compounds like *to:g+passa:ʔr* ‘train passenger’. Here too, if the first word projects an ω^{Min} to form $[\omega [\omega \text{ F}^{\text{?}}] [\omega \text{ FF}^{\text{?}}]]$, and thereby preserves its stød, it incurs a fatal violation of NONREC not shared by a candidate with one less ω^{Min} , $[\omega \text{ F} [\omega \text{ FF}^{\text{?}}]]$.

(9) *Tableau for Short-Long compound*

	$ \begin{array}{c} N_2 \\ \swarrow \quad \searrow \\ N_1 \qquad N_2 \\ (to:g) \quad (passa)(ge:r) \end{array} $	BINMAX-BR	NONREC	MATCH
a. →	$ \begin{array}{c} \omega \\ \swarrow \quad \searrow \\ \omega \qquad \qquad \omega \\ \quad \quad \\ F \quad F \quad F \\ to:g \quad passa \quad ge:ʔr \end{array} $		*	*
b.	$ \begin{array}{c} \omega \\ \swarrow \quad \searrow \\ \omega \qquad \qquad \omega \\ \quad \quad \\ F \quad F \quad F \\ to:ʔg \quad passa \quad ge:ʔr \end{array} $	e	**W	L

c.	$ \begin{array}{c} \omega \\ \swarrow \quad \downarrow \quad \searrow \\ \omega \quad \quad \quad \omega \quad \quad \quad \omega \\ \quad \quad \quad \quad \quad \quad \\ F \quad \quad \quad F \quad \quad \quad F \\ \text{to:}^?g \quad \text{passa} \quad \text{ge:}^?r \end{array} $	*W	L	**W
d.	$ \begin{array}{c} \omega \\ \swarrow \quad \downarrow \quad \searrow \\ F \quad \quad \quad F \quad \quad \quad F \\ \text{to:g} \quad \text{passa} \quad \text{ge:}^?r \end{array} $	*W	*e	*e

When the first word is monosyllabic, failure to project an ω^{Min} does not in itself cause a violation of BINMAX-BR; whether the first daughter of ω^{Max} is of category Ft or ω has no relevance for binarity, which counts nodes (or equivalently, branches) but does not inspect their category. Consider now compounds in which the first member is more than a single foot, such as *passage:~r+to:~g* ‘passenger train’.

(10) *Tableau for Long-Short compound*

	$ \begin{array}{c} N_2 \\ \swarrow \quad \searrow \\ N_1 \quad N_2 \\ (\text{passa})(\text{ge:r}) \quad (\text{to:g}) \end{array} $	BINMAX-BR	NONREC	MATCH
a. →	$ \begin{array}{c} \omega \\ \swarrow \quad \downarrow \quad \searrow \\ \omega \quad \quad \quad \omega \quad \quad \quad \omega \\ \quad \quad \quad \quad \quad \quad \\ F \quad \quad \quad F \quad \quad \quad F \\ \text{passa} \quad \text{ge:}^?r \quad \text{to:}^?g \end{array} $		*	*
b.	$ \begin{array}{c} \omega \\ \swarrow \quad \quad \quad \searrow \\ \omega \quad \quad \quad \omega \\ \swarrow \quad \downarrow \quad \searrow \quad \quad \quad \\ F \quad \quad \quad F \quad \quad \quad F \\ \text{passa} \quad \text{ge:}^?r \quad \text{to:}^?g \end{array} $	e	**W	L
c.	$ \begin{array}{c} \omega \\ \swarrow \quad \downarrow \quad \searrow \\ F \quad \quad \quad F \quad \quad \quad F \\ \text{passa} \quad \text{ge:r} \quad \text{to:}^?g \end{array} $	*W	L	**W

d.		*W	*e	*e
----	--	----	----	----

In (10), the first morphosyntactic word consists of two feet. When it projects its own ω^{Min} and keeps its $\text{st}\emptyset\text{d}$, as in (a–b), the ω^{Max} is perfectly binary, satisfying BINMAX-BR. Unlike in compounds with a short first member, embedding the two feet of *passage:r* ‘passenger’ directly under the ω^{Max} node, as in (c–d), results in a ternary-branching structure [ω FFF $^?$] or [ω FF [ω F $^?$]], in a violation of BINMAX-BR. The fact that *passage:r* projects an ω^{Min} here therefore establishes the ranking BINMAX-BR \gg NONREC.

The same holds for Long+Long compounds, *mutatis mutandis*:

(11) *Tableau for Long-Long compound*

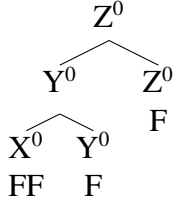
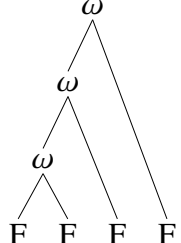
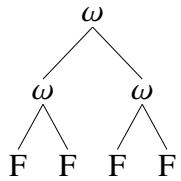
	BINMAX-BR	NONREC	MATCH
a. →		**	
b.	*W	*L	*W
	*W	*L	*W
c.	*W	*L	*W
	*W	L	**W
d.	*W	L	**W

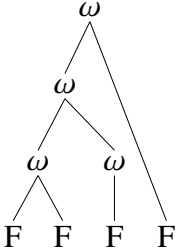
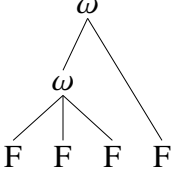
In sum, the first morphosyntactic word of a two-member compound does not always project its own ω^{Min} in Danish. The drive to perfectly match morphosyntactic structure cannot in itself override the anti-recursion imperative, so structure is minimized when possible. But as usual in OT analyses, the “when possible” caveat here is crucial, and is reliant on evaluation by an even higher-ranked constraint, in this case BINMAX-BR. On this analysis, an ω^{Min} will only be projected if the ω^{Max} above it would otherwise have more than two branches.

3 Analysis of three-word compounds

The above constraint ranking (BINMAX-BR \gg NONREC \gg MATCH(X^0, ω)) also makes predictions for the prosody of three-word compounds in Danish—namely, that two-word sub-compounds embedded inside three-word compounds receive the same prosody that they would if they occurred in isolation. That is, the prosody of larger compounds is what would be predicted if the compound prosody had been determined cyclically: first building the prosodic structure of the embedded two-word compound, then adding additional prosodic structure to incorporate the outer third word of the compound. For example, the three-word **[[LS] S]** compound contains the two-word **[LS]** compound (bolded throughout the tableau in (12)), which is parsed as $[\omega [\omega L] S]$ whether it appears by itself, or embedded in a three-word compound (12a). Other candidates that do not parse pseudo-cyclically fare worse. (12b) deviates from pseudo-cyclic parsing by not matching the embedded two-word compound $[\omega LS]$ to a prosodic word, incurring a fatal violation of MATCH. Candidates (12c) and (12d) avoid that MATCH violation, but parse the internal structure of the two-word compound with too much recursive structure (12c) or too little (12d), and lose to (12a).

(12) *Example of pseudo-cyclicity in a three-word compound*

		BINMAX-BR	NONREC	MATCH- X^0
a. \rightarrow			**	**
b.		e	**e	***W

<p>c.</p> 	<p>e</p>	<p>***W</p>	<p>*L</p>
<p>d.</p> 	<p>*W</p>	<p>*L</p>	<p>***W</p>

This pattern shows the interaction of BINMAX-BR and MATCH- X^0 . High-ranking BINMAX-BR compels the optimal output to be subdivided into binary-branching constituents. Although binarity has no preferences regarding the placements of these prosodic subdivisions, NONREC and MATCH- X^0 , exert the same pressures on sub-trees as they do on the tree as a whole: MATCH- X^0 selects the binary-branching prosodic constituency that best corresponds to the syntactic constituency, and NONREC prevents the building of excess prosodic words at any level of the tree.

This constraint set and ranking predicts analogous pseudo-cyclicity for all three-member compounds, which we verified using the JavaScript application SPOT (Bellik, Bellik, and Kalivoda, 2018) and the Excel extension OTWorkplace (Prince, Tesar, and Merchant, 2018). The predicted parsings of left-branching compounds are shown in (13). Right-branching compounds are predicted to be mirror images of these. (Here, ‘S’ means ‘short word’ (= 1 foot) and ‘L’ means ‘long word’ (= 2 feet).)

(13) *Predictions for three-word compounds in Danish*

<i>Syntax</i>	<i>Prosody</i>	<i>Syntax</i>	<i>Prosody</i>
[[S S] S]	[[S S ²] S ²]	[[L S] S]	[[[L ²] S ²] S ²]
[[S S] L]	[[S S ²] [L ²]]	[[L S] L]	[[[L ²] S ²] [L ²]]
[[S L] S]	[[S [L ²]] S ²]	[[L L] S]	[[[L ²] [L ²]] S ²]
[[SL] L]	[[S [L ²]] [L ²]]	[[L L] L]	[[[L ²] [L ²]] [L ²]]

To test these predictions, we recorded a Danish speaker reading a list of three-member compounds. These were both left-branching and right-branching. Subwords were selected that bear stød in isolation, allowing us to observe whether that stød appears or not in various compound positions. Recordings were examined in Praat (Boersma and Weenink, 2017). Stød was identified by glottalization and/or pitch drop during the second mora of a syllable (Fischer-Jørgensen, 1989). Our results were in line with the prediction of pseudocyclicity laid out above.

(14) *Left-branching*

- a. [_ω [_ω [_ω passa ge:²r] to:²g] vra:²g] ‘passenger train wreck’
- b. [_ω [_ω ru:g brø:²ds] to:²g] ‘rye bread train’
- c. [_ω [_ω da:g bo:²g] [_ω tera pi:²]] ‘diary therapy’

The fact that stød is present on *to:r[?]g*, *brø:[?]ds*, and *bo:[?]g* in (14) indicates that these words are ω -final, as predicted. Our analysis also correctly predicts the absence of stød on *ru:g* and *da:g*. Our consultant judged many right-branching compounds as degraded, but while they found the following awkward, they crucially pronounced them without stød on the second subword:

(15) *Right-branching*

- a. [ω [ω industri:[?]] [ω fo:d [tera pi:[?]]] ‘industry foot-therapy’
 b. [ω [ω fanta si:[?]] [ω sne: stor:[?]m]] ‘fantasy snowstorm’

Although these are constructed examples with unusual meanings, the lack of stød on *fo:d* ‘foot’ and *sne:* ‘snow’ suggests that these words are not ω -final. This can be explained on a cyclic account of ω -construction, or on the pseudo-cyclic but fully parallel analysis we provide using forms of MATCH- X^0 , NONREC, and BINMAX-BR.

4 Counting branches, not leaves

To derive the partial-matching and pseudo-cyclic effects seen above, the undominated binarity constraint must be satisfied by the building of additional prosodic structure. This is only possible with certain implementations of binarity. While binarity is a commonly-used prosodic well-formedness constraint-type (Ito and Mester, 2003; Sandalo and Truckenbrodt, 2002; Prieto, 2007; Selkirk, 2011; Elfner, 2012), different analyses have employed significantly different implementations. Broadly speaking, these can be divided into two types: branch-counting and leaf-counting. When only binary or ternary-branching nodes are considered, branch- and leaf-counting binarity often make the same predictions. However, when recursive structures and supra-ternary branching structures are taken into account, the two types of binarity make different predictions: branch-counting binarity can compel the building of recursive structure, but leaf-counting cannot. This section unpacks the differences between these two different implementations of binarity.

Branch-counting binarity requires a node to branch into two children. A violation of BINMAX-BR is incurred only by a node that branches into three or more children. The total number of dominated nodes (e.g., both its children and its more distant descendants) is irrelevant, as is their category. Consequently, a violation of branch-counting binarity can be avoided by building additional layers of prosodic structure, in which each node immediately dominates only two children. Branch-counting binarity has been employed in analyses of phrasing in Irish (Elfner, 2012), Kinyambo (Bellik and Kalivoda, 2016), and several languages in Kalivoda (2018), and we employ it here for the analysis of Danish compound word prosody.

Leaf-counting binarity, on the other hand, counts the number of nodes of the next-lower prosodic category that are dominated by a node. In the case of φ , leaf-counting constraints are concerned with the total number of dominated ω s, while any intermediate φ structure is irrelevant. A four-word phrase (φ (φ ω ω) (φ ω ω)) violates leaf-counting binarity despite maintaining strict binary branching. Conversely, a phrase (φ σ ω ω) violates branch-counting binarity, but satisfies leaf-counting binarity. Leaf-counting binarity constraints at the φ -level have been employed by Selkirk (2000), Sandalo and Truckenbrodt (2002), Prieto (2007), and Ito and Mester (2013).

Importantly for our purposes, leaf-counting binarity is not satisfied by building additional recursive structures, and consequently cannot derive the partial-matching results seen above for Danish compound words. We illustrate this difference between leaf-counting and branch-counting in (16).

(16) *Branch-counting versus leaf-counting*

	BINMAX-BRANCHES	BINMAX-LEAVES
<p>a. →</p> <pre> graph TD phi1[φ1] --> phi2[φ2] phi1 --> phi3[φ3] phi2 --> omega1[ω1] phi2 --> omega2[ω2] phi3 --> omega3[ω3] phi3 --> omega4[ω4] </pre>		*
<p>b.</p> <pre> graph TD phi1[φ1] --> phi2[φ2] phi1 --> omega4[ω4] phi2 --> phi3[φ3] phi2 --> omega3[ω3] phi3 --> omega1[ω1] phi3 --> omega2[ω2] </pre>	e	**W
<p>c.</p> <pre> graph TD phi1[φ1] --> omega1[ω1] phi1 --> omega2[ω2] phi1 --> omega3[ω3] phi1 --> omega4[ω4] </pre>	*W	*e

All candidates in (15) contain four prosodic words. However, their phonological phrasing differs, with the result that the two types of binarity prefer different candidates. Under branch-counting binarity, candidates (a) and (b) are perfect, since every φ in those prosodic trees branches into exactly two children. Candidate (c), however, incurs one violation of BINMAX-BRANCHES, since its φ_1 branches into four children.

In contrast, under leaf-counting binarity, every candidate incurs at least one violation, since all trees are rooted in φ s that ultimately dominate four (>2) prosodic words. Candidates (a) and (c) only contain one such φ , but candidate (b) contains two (φ_1, φ_2). Notice that the two forms of Binarity group different candidates together. Under branch-counting binarity, all violations can be eliminated by articulating the φ -structure sufficiently, as in (a) and (b), while under word-counting binarity, this escape is not available. Adding more layers of structure does not eliminate the fact that somewhere in the tree, more than two prosodic words are being grouped together. (In fact, unlike branch-counting binarity, leaf-counting has a potentially unbounded search space.) Thus, branch-counting binarity motivates the building of prosodic structure, and hence prosodic recursion, but leaf-counting binarity does not.

In our analysis of Danish compound words, we derived the partially-matching prosody found in Danish with a low-ranked MATCH- X^0 that is complemented by a high-ranked BINMAX-BR, with NONREC ranked in between. NONREC can be overridden in order to avoid a BINMAX-BR violation. If BINMAX-BR is replaced by BINMAX-LEAVES, partial matching is no longer motivated, and a flat structure wins instead. This is shown in the tableau in (17). The intended winner is candidate (a), which is perfectly binary in terms of its branches, thanks to its recursive structure, but which incurs a violation of BINMAX-LV because the topmost prosodic word dominates three (> 2) feet. In fact, all candidates incur one violation of BINMAX-LV, so the decision is made instead by NONREC. Consequently, (a) loses to (c), which has no recursive

structure. Moreover, the desired optimum (a) also ties with (d), where the shorter X^0 receives its own prosodic word but the longer one does not.

(17) *Ineffectiveness of leaf-counting in Danish*

		BINMAX-LEAVES	NONREC	MATCH- X^0
	$ \begin{array}{c} N_2 \\ \swarrow \quad \searrow \\ N_1 \quad N_2 \\ (to:g) \quad (passa)(ge:r) \end{array} $			
a. →	$ \begin{array}{c} \omega \\ \swarrow \quad \searrow \\ F \quad \omega \\ \swarrow \quad \downarrow \quad \searrow \\ F \quad F \quad F \\ to:g \quad passa \quad ge:r \end{array} $	*	*	*
b.	$ \begin{array}{c} \omega \\ \swarrow \quad \searrow \\ \omega \quad \omega \\ \downarrow \quad \swarrow \quad \searrow \\ F \quad F \quad F \\ to:g \quad passa \quad ge:r \end{array} $	*e	**W	L
c.	$ \begin{array}{c} \omega \\ \swarrow \quad \downarrow \quad \searrow \\ F \quad F \quad F \\ to:g \quad passa \quad ge:r \end{array} $	*e	L	**W
d.	$ \begin{array}{c} \omega \\ \swarrow \quad \downarrow \quad \searrow \\ \omega \quad F \quad F \\ \downarrow \quad \downarrow \quad \downarrow \\ F \quad F \quad F \\ to:g \quad passa \quad ge:r \end{array} $	*e	*e	*e

In modeling Danish compound prosody, then, binarity must count branches (immediate children), rather than leaves (all descendents). Only branch-counting binarity derives the partial-matching effect seen in Danish words; leaf-counting cannot motivate ω -recursion.

5 Typological predictions

The proposed partial-matching analysis of Danish compounds gives a non-uniform account, where sometimes compounds are recursive and sometimes they are not. This is novel and somewhat unusual in the treatment of compounds. What does this set of constraints predict for the typology of compound prosodies? We address this question using the JavaScript application SPOT (Bellik et al., 2018) and the Excel extension OTWorkplace (Prince et al., 2018). We used SPOT to generate a comprehensive violation tableau for the OT system in question. The constraint set for the system

was $CON = \{MATCH-X^0, BINMAX-BR, NONREC\}$, as above. The space of syntactic inputs consisted of 16 binary branching compounds, comprised of three L or S syntactic words, as well as the four two-word compounds shown in Section 2. GEN was a function that yields all Weakly Layered prosodic trees that were rooted in a prosodic word and did not contain vacuous recursion. The resulting violation tableau was entered into OTWorkplace to calculate a factorial typology of compound prosodies.

The resulting factorial typology contained three languages, shown in Table 2, with different degrees of faithfulness in the syntax-prosody mapping. The most faithful mapping occurs in L1, which represents languages where compound prosody exactly matches input syntax (Perfect Match), because $MATCH-X^0$ outranks $BINMAX-BR$ and $NONREC$. English instantiates an L1-type language, since English compound prosody is essentially perfectly matching (Lieberman and Prince, 1977; Cinque, 1993). At the other end of the spectrum of syntax-prosody correspondence, L3 represents languages where recursive syntactic words become prosodically flat. This unfaithful mapping of compound structure occurs because NonRecursivity outranks both $MATCH$ and $BINMAX-BR$. Such flat compound structure has been reported for Greek (Nespor and Vogel, 1986), where a compound constitutes a single stress domain. Intermediate between Perfect Matching L1 and Flat L3 is Partial Matching L2. In L2, recursive structures occur only where they eliminate violations of $BINMAX-BR$, as seen above for two-word compounds in Danish. Although $MATCH$ is too low-ranked to drive recursive structure-building, high-ranked $BINMAX-BR$ performs this function, and $MATCH$ motivates the choice of how to group the terminals.

(18) *Factorial typology of compound prosodies*¹

	L1 Perfect Match M >> NR	L2 Partial Match B >> NR >> M	L3 Flat NR >> M, B
a. [[F] [F]]	[[F] [F]]	[FF]	[FF]
b. [[F] [FF]]	[[F] [FF]]	[F [FF]]	[FFF]
c. [[FF] [F]]	[[FF] [F]]	[[FF] F]	[FFF]
d. [[FF] [FF]]	[[FF] [FF]]	[[FF] [FF]]	[FFFF]
e. [[[F] [F]] [F]]	[[[F] [F]] [F]]	[[FF] F]	[FFF]
f. [[[F] [F]] [FF]]	[[[F] [F]] [FF]]	[[FF] [FF]]	[FFFF]
g. [[[F] [FF]] [F]]	[[[F] [FF]] [F]]	[[F [FF]] F]	[FFFF]
h. [[[F] [FF]] [FF]]	[[[F] [FF]] [FF]]	[[F [FF]] [FF]]	[FFFFF]

¹The analysis also considered right-branching structures, which we omit here since they behave identically to left-branching structures.

i.	[[[FF] [F]] [F]]	[[[FF] [F]] [F]]	[[[FF] F] F]	[FFFF]
j.	[[[FF] [F]] [FF]]	[[[FF] [F]] [FF]]	[[[FF] F] [FF]]	[FFFFF]
k.	[[[FF] [FF]] [F]]	[[[FF] [FF]] [F]]	[[[FF] [FF]] F]	[FFFFF]
l.	[[[FF] [FF]] [FF]]	[[[FF] [FF]] [FF]]	[[[FF] [FF]] [FF]]	[FFFFFF]

This constraint set was able to derived the novel result of non-uniform matching in compound prosody while also predicting uniform results when other constraint rankings obtain. In addition, all three languages in the factorial typology are attested. Thus, while the non-uniform, partial-matching prosody in our account of Danish may seem unusual, it can be predicted using a small set of conventional constraints, which does not affect the predicted typology adversely.

6 Phrasal compounds

All the compound prosodies predicted by the typology above are attested in real languages. However, not every attested compound prosody is predicted by our OT system. For example, in the investigation of compound prosodies above, we require every maximal X^0 map to a prosodic word. However, cross-linguistically, the maximal X^0 in a compounds can map to a phonological phrase. Ito and Mester (2007) discuss facts in Japanese which argue in favor of non-uniform, size-dependent compound prosody. On the basis of rendaku voicing, junctural accent, and other diagnostics, they argue that Japanese compounds can have at least the following forms:

- (19) *Shapes of Japanese compounds* (Ito and Mester, 2007)
- a. $[\omega [\omega \omega] \omega]$ *hoken-gaisha bánare* ‘movement from insurance cos.’
 - b. $[\omega \omega [\omega \omega \omega]]$ *genkin fúri-komi* ‘cash transfer’
 - c. $(\varphi \omega [\omega \omega \omega])$ *hatsu kao-áwase* ‘first face-to-face meeting’
 - d. $(\varphi(\varphi \omega)(\varphi [\omega \omega \omega]))$ *zénkoku kaisha-ánnai* ‘nationwide corporate guide’

The within-word recursion seen in (19a–b) is similar to what we have observed in Danish, but phrasal compounds like those shown in (19a–b) were not considered as candidates in our system. What we’ve developed here may be a slice of larger typology, for a system in which GEN may map the maximal X^0 to a φ instead of an ω . This relaxation of GEN could be compensated for with a violable constraint $\text{MATCH}(X^{0\text{Max}}, \omega^{\text{Max}})$, following Ishihara’s (2014) formulation of a phrase-level equivalent:

- (20) **MATCHPHRASE-MAX** (Ishihara, 2014)
 A maximal lexical projection in syntactic constituent structure (a lexical XP that is not immediately dominated by another lexical XP) must be matched by a corresponding maximal prosodic constituent in phonological representation (a PPhrase that is not immediately dominated by another PPhrase, φ^{Max}).

We leave the study of this larger system for future work, but the languages in (18) will be present when $\text{MATCH}(X^{0\text{Max}}, \omega^{\text{Max}})$ is undominated.

7 Conclusion

In this paper, we have followed up on a proposal made by Ito and Mester (2015), namely that the prosodic structure of Danish compounds determines the context-sensitive presence or absence of *stød*. A simple OT system involving three constraints, $\text{MATCH}(X^0, \omega)$, NONRECURSIVITY , and BINMAX-BRANCHES derives the prosodic structures diagnosed by disappearing *stød*. The constraint ranking for Danish, $\text{BINMAX-BR} \gg \text{NONREC} \gg \text{MATCH-X}^0$, ensures that prosodic structure will be non-recursive, contra MATCH , unless the absence of recursive structure results in a ternary-branching structure.

The analysis presented here underscores the importance of carefully defining binarity constraints. In Danish, replacing BINMAX-BRANCHES with BINMAX-LEAVES does not derive the observed partial matching effect. However, evidence from phenomena in other languages points toward several co-existing formulations of binarity. For example, Japanese phrasal compounding, as well as Japanese phonological phrasing, seem to require some form of leaf-counting binarity (Ito and Mester, 2007; 2013). In addition to the leaf-counting vs. branch-counting distinction and the categorical vs. gradient distinction, there are a number of subtle variations on the same theme. Elordieta (2006) has proposed a binarity constraint concerned only with the leftmost φ in ι . Reversing this, Prieto (2007) argues for a leaf-counting binarity constraint on the head φ of ι , which in Spanish is the rightmost in ι . In addition, Shinya, Selkirk, and Kawahara (2004) have investigated the moraic length of phonological phrases, and found a prosodic distinction between the behavior of, e.g., 5μ and 7μ words in certain φ -environments, and Selkirk (2011) cites several studies positing “prosodic size effects [...] that appear to depend on brute syllable count and are not reducible to prosodic binarity”. Whether such finer-grained effects can be assimilated to some form of binarity constraint family remains to be seen.

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