THE STRENGTH OF BINDINGS VS. THEIR PHONOTACTIC PREFERABILITY. COMPUTATIONAL ANALYSIS IN BEATS-AND-BINDING PHONOLOGY.

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Abstract

The aim of this article is to present some of the results of a computational analysis, included in Michalski (2004), within the model of phonotactics employed in Beats-and-Binding Phonology (see Dziubalska-Kołaczyk 2002). The article discusses the correlation between the inherent strength of bindings underlying various combinations of beats (B) and non-beats (n) and the Beats-and-Binding-preferred medial double consonant clusters. It will be shown that there is a substantial correlation between the inherent strength of a given binding and the number of sonority sequence combinations, defined as finite, in which such a binding may manifest itself. For example, a binding in which a non-beat is bound to a following beat (n→B) is not only inherently stronger than a reverse binding (B←n), but also it can manifest itself through a higher number of sonority sequences within Beats-and-Binding Preferred Cluster Spaces (see Dziubalska-Kołaczyk 2002: Chapter Five) than the other one. In the article, a hierarchy of the strengths of binding will be presented, followed by the results of the computational analysis of how widespread each type of binding is or may be within medial double consonant clusters.

1. Introduction

This article presents some of the results of a computational analysis, first described in Michalski (2004), which aimed at (1) providing evidence for (Canonical) Beats-and-Binding Phonology (see Dziubalska-Kołaczyk 2002) being inherently coherent with respect the its theory of bindings and to its model of phonotactics (including the Preferred Cluster Spaces), and which (2) proposed a few phonological devices to be added to the Beats-and-Binding framework under the name Enhanced Beats-and-Binding Phonology. Essentially, this meant that Michalski (2004) used a somewhat circular way of adding some novelty to show that the existing theory was correct, and used the existing theoretical inventory to show that the new bits were what the theory had been waiting for since its conception. As bold as the move might have appeared at the time, it had at least one eye-catching effect: the crop of terminology. The parentheses enclosing the word 'canonical' in the name of the original theory stem from the fact that the additions put forward as the 'enhanced' rendition of the theory were considerable enough to cause confusion as to whether they still operated under the same theory. Hence, for the sake of clarity, the original model presented in Dziubalska-Kołaczyk (2002) was dubbed Canonical Beats-and-Binding Phonology (hereinafter CBBP), while all the proposed additions were labelled Enhanced Beats-and-Binding Phonology (hereinafter EBBP). To complicate things even more, the generic term 'Beats-and-Binding' (or 'B&B') was used to refer to the large portion of CBBP which was left intact, and incorporated into EBBP without objection. In the following description, the basics of Beats-and-Binding as such, and the essential discrepancies between CBBP and EBBP will be given, plus parts of the methodology and of the outcome of analytical endeavour performed in Michalski (2004). For practical reasons, large portions of the thesis in question will be recycled hereinafter.

2. The basics of Beats-and-Binding

2.1. The foundations of the framework

Beats-and-Binding Phonology, as proposed in Dziubalska-Kołaczyk (2002) (which in turn is a further development of the version put forward in Dziubalska-Kołaczyk 1995), is a theory that follows the epistemology of Natural Linguistics. What is entailed by this statement is that Beats-and-Binding Phonology is "explicitly constructed as a *preference theory* rather than a general descriptive theory, and [employs] the epistemological approach of *functional explanation*." (Dziubalska-Kołaczyk 2002: 73) *Preference* implies a choice to be possible between concurrent alternatives. *Function* implies a goal to be reached by making choices. Since Natural Linguistics speaks of natural, i.e. human, languages, linguistic choices are to be made by human agents, and it is they who have a goal in choosing the actual alternative. In this respect, Beats-and-Binding Phonology is a theory of which alternatives are preferred to others in order to perform a given function, and reach a preset goal. The notions of *preference* and *function*, crucial to the higher-order framework of Natural Linguistics, apply here as the highest-order epistemological devices.

2.2. The Beat

"In Beats-and-Binding phonology, a 'beat' *is a regularly recurring skeletal prosodic unit of phonological representation, of a size corresponding to that of a segment*." (Dziubalska-Kołaczyk 2002: 86) There may be two types of beat. "In all languages, it is a unit of the rhythmic or timing tier: the timing beat." (Dziubalska-Kołaczyk 2002: 87) As a unit of rhythm, the beat is the Beats-and-Binding counterpart of the classical unit of the syllable (or rather the syllabic Nucleus). Speakers of a language may count beats and the number of beats counted in a given utterance will usually be the same as the number of syllables if those were to be counted.

Apart from the timing beat, there exists the quantity beat, which is roughly the Beats-and-Binding counterpart to the mora, which has the feature of weight. (Please notice that this article will largely omit the details behind the quantity beat, as it appears irrelevant to the notion of intersegmental bindings; for further reference see Dziubalska-Kołaczyk 2002) What is important, however, is that there is a potential terminological confusion as to which beat is which, and it will be proposed in the next paragraph how to distinguish between beats (presently, timing beats) and weights (presently, quantity beats).

2.3. The Bindings

In CBBP, "[beats] (B) and non-beats (n) in a sequence are joined by means of sonority-based bindings." (Dziubalska-Kołaczyk 2002: 94)

> The bindings are binary, i.e., e.g., in a sequence {BnB} there are maximally two bindings, i.e., a B←n binding (a non-beat is bound to the preceding beat) and an n→B binding (a non-beat is bound to the following beat), i.e. {B←n n→B}. A beat, however, may potentially stay alone while a non-beat must be bound to a beat. Thus, in the {BnB} sequence there may alternatively be one binding only, combined with a single beat, i.e., either {B n→B} or {B←n B}. (Dziubalska-Kołaczyk 2002: 94)

What this implies that (1) it is possible for a non-beat to be left unbound, on the condition that there is no beat neighbouring on the non-beat, that (2) a non-beat must be bound to at least one beat if there is any beat in the direct adjacency of the non-beat, and that (3) beats are free to bind non-beats that appear in their direct adjacency. The last conclusion was utilised in EBBP to define extended bindings, devices that help to describe possible phonological sub-units consisting of a beat and more than one non-beat (see Michalski 2004). As regards the types of bindings recognised in CBBP, the two types are not given equal rights.

> The two bindings differ in strength: the n→B binding, i.e., the binding of a non-beat to the following beat (preferentially realized by a /CV/ sequence), is always stronger than the B←n binding, i.e., the binding of a non-beat to the preceding beat (preferentially realized by a /VC/ sequence). I.e., n→B > (read: stronger than) B←n.
> This preference refers to the position of a non-beat with respect to the beat: sonority distances between a non-beat and a beat being equal, the non-beat *preceding* the beat is bound more strongly to it than the one following. (Dziubalska-Kołaczyk 2002: 94)

The inequality of the strength that different bindings have in CBBP may be translated into the notion that the strength of a binding depends upon the direction in which binding takes place. If viewed from such a perspective, the strength of a binding in which the beat is preceded by the non-beat is always higher than the strength of the mirror-image binding, i.e. a binding in which, all other conditions being the same, the order of segments is reversed. In EBBP, this dependence of strength upon the direction of binding is called *Strength by Direction* (see Michalski 2004). The reason for this strength dependence being mentioned already in this paragraph is that in section 2.8, yet another type of strength dependence will be presented, one that is inspired by CBBP, but whose explicit definition is introduced into Beats-and-Binding by EBBP, namely *Strength by Length*.

2.4. Some basics of CBBP notation

CBBP employs a three-tier notation. There are separate tiers to notate timing beats (and non-beats), speech segments as such, and quantity beats (see Dziubalska-Kołaczyk 2002: 105). Two examples of CBBP notation are given below.

```
n         B         n  timing tier bindings
|  n→B    |   B←n   |
k         æ         t  segmental tier
          |         |
          b         b  weight tier
```

(1) The English word “cat” in CBBP (see Dziubalska-Kołaczyk 2002: 105)

```
n         B         n  timing tier bindings
|  n→B    |   B←n   |
k         ɔː        t  segmental tier
        /    \
      b        b    b  weight tier
```

(2) The English word “caught” in CBBP (see Dziubalska-Kołaczyk 2002: 105)

It should be noted that through Michalski (2004), EBBP brought in a change in notation, but there is no need to present all its details. The most important difference is that EBBP dubs ‘tiers’ as ‘layers’, and uses ‘b’ for what it simply calls ‘beats’, whereas CBBP would call those devices ‘timing beats’, and notate them as ‘B’. Thus, beats and non-beats, all referring to speech segments, are notated with small letters, while capitals ‘B’ and ‘N’ are used for other purposes. Finally, CBBP’s ‘quantity beats’ are dubbed ‘weights’ under EBBP, and notated as ‘w’ on the weight layer. (For further reference see Michalski 2004.)

2.5. The apparent clash within CBBP, or how EBBP came about

There is an apparent clash within CBBP as regards the theory of binding as such (see Dziubalska-Kołaczyk 2002: Chapter Four), and the model of phonotactics that follows (see Dziubalska-Kołaczyk 2002: Chapter Five). The latter appears somewhat incompatible with the former. Most notably, the general model of phonology speaks of an underlying (deep, phonemic, phonological) level of representation, and uses the terms *beat*, *non-beat*, and *binding*, quite extensively, whereas the specific model of phonotactics concentrates on a surface (phonetic) level of representation, and uses the terms *vowel, consonant, and cluster*, in the description. There are only a few instances where the model of phonotactics actually does operate on Beats-and-Binding-specific terminology, such as *beat*, or *binding*. These are the defining conditions for Cluster Spaces and illustrative figures used in Dziubalska-Kołaczyk (2002: Chapter Five). Otherwise, the clusters are not described by means of bindings, even though the sonority of the clusters is an underlying feature, so it would be possible to relate the clusters to sonority-driven bindings. Such is the case in EBBP, where CBBP-preferred clusters are analysed through any underlying bindings that may concern segments of a given cluster. Thus, a substantial piece of evidence that the two models are in fact mutually coherent was sought for, and then successfully delivered in Michalski (2004), where phonetically defined phonotactical preferences of CBBP were juxtaposed with phonologically defined intersegmental binding preferences of CBBP, and EBBP as well.

2.6. The novelty of EBBP. Primary vs. extended bindings

What is known as bindings in CBBP has been translated in EBBP into primary bindings, and notated with the customary CBBP arrows "→," and "←." The two types of primary bindings inherited from CBBP have their own names in EBBP. The {n→b} type of binding, notated as n→B in CBBP (with the letters and the arrow emboldened; this is the case in all bindings in CBBP, but not in EBBP), is called the primary fore binding. The {b←n} type of binding, on the other hand, notated as B←n in CBBP, is called the primary aft binding. The somewhat marine terminology is used to emphasise the direction of the binding in respect to both the binding beat and the preferred mode of building speech chains in their underlying forms, namely right-to-left. If this direction be true as a universal phonological preference, then what appears to the left of a beat in a linear, segmental representation may be said stand at the fore of this beat, whereas what appears to the right of a beat may be said to occupy the aft. (Please notice that the expression 'linear' does not mean that B&B views segments as linear feature bundles of the SPE type; on the other hand, there seems to be no written evidence that B&B should be autosegmental, either.)

n→b a primary fore binding	b←n a primary aft binding

(3) Primary bindings in EBBP

The direction of the arrows used in CBBP/EBBP notation may be a bit misleading, but a lot here depends on denotation and connotation. The direction of the arrows, "→" and "←," is aimed at displaying the dependence between beats and non-beat.

The arrows always point to a beat in order to show that it is the beat, not the non-beat, that governs a binding. On the other hand, it is EBBP's stance that fore bindings, indicated with "→" arrows, should come into being prior to aft bindings, hence the direction of phonological processing at the time of fore bindings creation is in fact "←", i.e. right-to-left. This bit of confusion was not resolved in Michalski (2004), the reason being that if the arrows should reflect the actual direction of binding, i.e. from the non-beat to the beat, then there would have been one more amendment to CBBP introduced by EBBP, perhaps one too many for one sitting.

What was introduced into Beats-and-Binding in Michalski (2004) was the notion of extended bindings. Such bindings are potentially possible to come into being between a beat and those non-beats in a series neighbouring on the beat that form an uninterrupted sonority slope towards the beat, in either direction. For example, in the English word (4)

(4) strand /strænd/,

there can possibly be two extended bindings, one in the /træ/ sequence, the other in the /ænd/ sequence. Notice that the initial /s/ is left unbound, since its sonority excludes it from a slope towards the /æ/ beat. Neither CBBP nor EBBP do require that every segment be involved in a binding. Nor does B&B require total parsing of segments (as opposed to Government Phonology or Optimality Theory, for example; see, for example, Scheer 2004 and Hammond 1999 for comparison). If a non-beat is not adjacent to a beat, no primary binding is possible, whereas an extended binding is only possible if the non-beat is part of a sonority slope towards a non-beat that is already bound to a beat in a primary binding. Extended bindings are notated with EBBP-specific arrows "↣," and "↢." When a single-line notation is used, the extended arrows are drawn instead of the primary arrows to indicate that there is an extended binding between a beat and two or more non-beats in a row. If a primary arrow appears between a beat and a non-beat it is presumed that there is no extended binding in which these two segments would take part at the same time or that such an extended binding has no been attested or that it is not relevant for a given parse. For example, in (5)

(5) /{s[(tr)↣æ↢(nd)]}/

the extended arrows indicate that the /tr/ and /nd/ sequences, as wholes, are subject to extended bindings governed by the /æ/ beat (or at least there is a possibility that they are). Alongside these extended bindings, there are still two primary bindings in this chain, namely /{r→æ}/ and /{æ←n}/. The actual relations between primary and extended bindings are language-specific, however the preferred relation is the primary bindings being stronger than extended bindings. Should it be necessary to indicate the existence of underlying bindings of both types at the same time, EBBP proposed that primary and extended bindings be notated on separate layers of representation. Otherwise, it appears enough to indicate extended bindings if there are any, since underneath any extended binding, there is a primary binding between the beat and the adjacent non-beat.

s	t	r	æ	n	d	surface segmental layer
		r→	æ	←n		primary bindings layer
	(tr)↣		æ	↢(nd)		extended bindings layer

(6) Primary and extended bindings notated on separate layers of EBBP representation

For syllable-aware frameworks, the extended type of bindings is essentially akin to onsets and codas, provided that a specific definition of syllable boundaries is used. If the syllable should extend in either direction from the nucleus no farther than to the last segment that forms an uninterrupted sonority slope towards the nucleus, then all segments within such a syllable may be subject to an extended binding, an extended fore binding for segments left of the syllabic centre constituted by the beat, or an extended aft binding for segments right of the beat. As is the case with primary bindings, fore bindings are notated with a right-pointing arrow, aft bindings with a left-pointing one.

n→b a primary fore binding	b←n a primary aft binding
(nn)↣b an extended double fore binding	b↢(nn) an extended double aft binding
(nnn)↣b an extended triple fore binding	b↢(nnn) an extended triple aft binding

(7) Primary bindings and extended bindings of different lengths

It appears necessary to stress that extended bindings are supposed to be phonological devices that find manifestation in actual phonetic realisation, not the other way round. As is the case with primary bindings, not every surface sequence of desired sonority is a manifestation of an underlying binding, since a beat and a non-beat may stand next to each other in casual, non-binding manner (see Dziubalska-Kołaczyk 2002: 94). The contrary is true, i.e. every underlying binding should have a phonetic realisation.

Extended bindings are unwelcome by design. Their phonetic realisations are consonant clusters, which violate the universally preferred CV structure. Any extended bindings existing in a phonological representation add to complexity thereof, and lead to confusion in phonological processing. Depending on language-specific conditions or constraints, extended bindings may be harmless to phonological structures, but they may as well inflict phonological difficulty upon a language. There is a universal preference for not having extended bindings in a language, best manifested by the fact that around 70% of the languages of the world do not exhibit consonant clusters (see Maddieson 1999), the only obvious phonetic realisations of extended bindings under this theory.

The avoidance of extended bindings is also computable from the model of phonotactics employed in CBBP (see Dziubalska-Kołaczyk 2002: Chapter Five), and will be demonstrated in section 3 of this paper.

2.7. The strength of the new binding inventory. Beat field. Right-Hand Alignment

The beat field was introduced in Michalski (2004), under specific conditions, as the EBBP corresponding item to the syllable. The most important feature of the beat field is that it is not a primary phonological unit, and should it ever be considered a unit in phonology, then it would be a derived, analytical unit rather than a productive one, otherwise the beat field would be a grievous denial of CBBP and its disbelief in the syllable. Beat fields are subject to further constraints. There is always one and only one beat field maintained around a beat. Beat fields are always centred on beats.

The most general condition that a non-beat must fulfil to be included in a beat field is given below:

In order to constitute part of a beat field, a non-beat must be bound to the beat that governs the beat field, in a primary binding or in an extended binding.

(8) General condition for the inclusion of non-beats in beat fields

Essentially, this condition is akin to the principle that concerns segments parsed into onsets or codas in those definitions of the syllable that make use of sonority value when defining syllabic constituency. Notice, however, that similarly to a formulation of the Sonority Sequencing Generalisation, two adjacent consonants of the same sonority would not fit into a single syllable. "In any syllable, there is a segment constituting a sonority peak that is preceded and/or followed by a sequence of segments with progressively decreasing sonority values." (Selkirk 1984: 116) Basically, EBBP proposes the same condition for beat fields, the beat being the sonority peak. Thus, a beat field must not extend beyond either of the sonority slopes that spread from or towards the beat.

Please notice that in Beats-and-Binding there are seven levels of speech segment sonority. These include three levels for obstruents: plosive, affricate, fricative; three levels for sonorants: nasal, liquid, semivowel; plus a separate level for vowels. In order to form a slope, it is sufficient to combine two or more segments whose sonority classes form a chain of either positive or negative sonority increments. There is no requirement for consonants in an extended binding to belong to separate classes of the obstruent-sonorant distinction. EBBP allows for two or more obstruents or sonorants belonging to one extended binding. This stands in opposition to such frameworks as (Standard) Government Phonology, where a branching onset can only be constructed from an obstruent followed by a sonorant (further conditions being irrelevant here; see Scheer 2004 for discussion on constituents in GP).

For the sake of nomenclature, the part of a beat field that precedes the beat itself may be called the onbeat, whereas the part of a beat field that follows the beat may be called the offbeat. EBBP does not insist on actually using this terminology.

May it be proposed that the four types of bindings recognised in EBBP form the following relations of strength:

	primary bindings	extended bindings
fore bindings	the strongest	weaker than primary fore; stronger than extended aft
aft bindings	weaker than primary fore; stronger than extended aft	the weakest

(9) Comparative Binding Strength Type Table

As visualised in the table above, there certainly is one type of binding that is the strongest of the four, and one that is the weakest. As regards the two other types, however, the strength relation is not that obvious. Michalski (2004) aimed at dissolving this dilemma through logical and mathematical analysis of what is computable from the model of phonotactics employed in CBBP (see Dziubalska-Kołaczyk 2002: Chapter Five). The analysis was not without a prediction, though. It appeared reasonable to take a CBBB-like way of thinking and state that the primary aft binding should be stronger than the extended fore binding. Firstly, the primary aft binding appears more universal than the primary fore binding. The aft binding in question is manifested by any syllable that has a coda (e.g. VC, CVC, CVCC), whereas the fore binding in question translates into syllables that have onsets that necessarily occupy at least two skeletal slots (e.g. CCV, CCVC, CCVCC). Since there is a universal tendency to maintain a simple syllabic structure in languages of the world (see Maddieson 1999), the primary aft binding appears by far preferred to the extended fore binding. One context needs further explanation, though. When there are two beat fields neighbouring each other, a conflict of bindings might potentially take place between the beats. For example, in (10),

(10) London /ˈlʌndən/

the medial /nd/ cluster is subject to two primary bindings, /{ʌ←n}/ and /{d→ə}/, and, seemingly, to one extended binding, /{ʌ⤆(nd)}/. Consequently, the /d/ segment appears double-bound, and should possibly belong in two beat fields, /{[l→ʌ⤆(nd)]}/ and /{[d→ə←n]}/. Since, however, beat fields are supposed to be akin to the syllable, and syllables usually do not overlap, it appears necessary to provide EBBP with a mechanism to recognise boundaries between beat fields in case there should be ownership conflicts like the one in (10). Please note that since EBBP is a preference theory, not embedded within the generative tradition, full syllabic parsing is not required, and in fact not endorsed. Rather, the boundary recognition mechanism is supposed to predict where phonological chains split when phenomena traditionally known as syllable deletion, and reduplication apply. Hence, the mechanism is generative in formulation, but natural in application. As is the case with syllabic frameworks, where codas and onsets do not share skeletal slots, no element of a segmental layer in EBBP may belong in more than one beat field, though as long as no phonological process whose domain is the beat field applies, this condition does not appear crucial. Therefore, the exemplary /d/ segment is subject to what was introduced in EBBP as Right-Hand Alignment.

Should a non-beat appear anywhere between two beats, directly or indirectly, and should the sonority value of the non-beat make it subject to binding by both beats at the same time, the non-beat shall be bound to the following beat, i.e. the beat that appears to the right of the non-beat in question, and shall be assigned to the beat field created by that beat, at the expense of the preceding beat, i.e. the one that stands to left.

(11) Right-Hand Alignment definition for beat field membership of non-beats

As a result, Right-Hand Alignment, henceforth also known as RHA, ensures that in (10), while the /d/ non-beat may be phonologically visible to both the /ʌ/ beat and the /ə/ beat, it is the /ə/ beat that has priority in assigning the /d/ non-beat to a beat field. Hence, the proposed underlying representation of (10) is presented as (12):

(12) London /{[l→ʌ←n]|[d→ə←n]}/.

Clearly, this approach resembles the so-called Onset-Rhyme syllable structure, where the Onset contains one or two consonants that form a non-falling sonority sequence, and the Rhyme has the obligatory sub-constituent of the Nucleus, single or branching, and may additionally be enriched by a non-branching or a branching Coda, attached directly to the Rhyme, not being as prominent as the Nucleus (see, for example, Gussmann 2002 or van der Hulst and Ritter 1999a). Consequently, while a beat field spreads from the beat in both directions of segmental layers, the two parts of the beat field differ in strength. Notice, however, that in EBBP the governing relations depend on the features of the bindings created between segments, and not on the charm of other properties of the segments themselves, as (Standard) Government Phonology would have it, for example (see Scheer 2004 for discussion on government in SGP). As is the case with bindings, where fore bindings are stronger than aft bindings of the same sonority distance and length, the fore of a beat field should be stronger than the aft. However, the fore would certainly be uniformly stronger than the aft if only there were no other types of bindings than primary. In those beat fields in which at least one extended binding is found, the strength relation between the fore and the aft may be subject to the binding length distinction operating alongside the binding direction distinction.

2.8. Strength-By-Direction and Strength-by-Length

As has been mentioned earlier, bindings differ in strength, and this difference comes not only from the direction of the bindings, as presumed in CBBP, but also from the length of those, as introduced in EBBP. May it be thus posited that there is a universal tendency in language to strive for the maximal strength of bindings that is attainable. Essentially, this means that a language should prefer those bindings that are stronger by direction, fore bindings being stronger than aft bindings, and those that are stronger by length, primary bindings being stronger than extended bindings. Furthermore, two categories of strength may be easily defined for the sake of nomenclature.

Strength by Direction, where fore bindings are stronger than aft bindings because of the sonority contrast being greater in CV transitions than in VC transitions (see Dziubalska-Kołaczyk 2002: Chapter Four),

Strength by Length, where primary bindings are stronger than extended bindings because of the sonority contrast being greater and more immediate in CV and VC transitions than in CCV and VCC transitions, not to speak of sonority slopes in CCCV and VCCC transitions (see Michalski 2004: Chapter 4).

Obviously, there can be only one type of binding that meets both strength criteria at the same time, that being the primary fore binding ($\{n \rightarrow b\}$), best realised as CV, which in turn is universally-attestable as the most prominent (general) sonority sequence. What was successfully computed in Michalski (2004) is that within CBBP-preferred medial consonant clusters, the primary fore binding is the least susceptible to breaking, and is the most widespread one.

3. Computational evidence for Right-Hand Alignment or what EBBP was all about

3.1. Introduction

This section concerns the space of potential evidence for EBBP Right-Hand Alignment that is extractable from CBBP (see Dziubalska-Kołaczyk 2002). The evidence comes from Preferred Cluster Spaces designed for CBBP, specifically those Cluster Spaces that concern medial consonant clusters. The aim is to show that among CBBP-preferred consonant clusters, there is a mathematical preference for such ordering of the consonants with respect to their sonority that fits the definition of Right-Hand Alignment, as well as the claim that primary bindings are preferred to extended bindings, and that fore bindings are preferred to aft bindings.

3.2. Sonority as the basis for Preferred Cluster Spaces

A word should be given to the source of Beats-and-Binding Preferred Cluster Spaces.

> Clusters, in order to survive, must be sustained by some force counteracting the overwhelming tendency to reduce towards CV's. This force is a contrast of sonority. … The conditions of co-occurrence of segments in clusters are specified with reference to the phonological parameter of sonority. The *Optimal Sonority Distance Principle (OSDP)* defines the way in which segments should order themselves in a successful sequence: the relations between sonority are neither expected to be maximal nor minimal, to increase or decrease, but to be optimal with respect to the output cluster. … Optimal sonority relations take the form of well-formedness conditions holding for double, triple, and n-member clusters in all positions in a word, i.e. initial, medial, and final. (Dziubalska-Kołaczyk 2002: 114)

The previously mentioned sonority scale has the following values:

vowels	semivowels	liquids	nasals	fricatives	affricates	plosives
0	1	2	3	4	5	6

(13) Canonical Beats-and-Binding sonority scale (after Dziubalska-Kołaczyk 2002: 114)

Notice that the scale is oblivious to the voicing parameter of obstruents, and to the place of articulation. As dangerous as it would be for a phonological theory to overlook the place of articulation (see Scheer 2004 for some discussion), it should be noted that Beats-and-Binding actually does acknowledge the place of articulation (and phonation) influencing phonotactical preferences, although, presently, it does not state explicitly how big this influence should be (see Dziubalska-Kołaczyk 2005).

Below, a number of preferred-cluster sets will be presented that shall help to show that Right-Hand Alignment can be drawn straight off the model of phonotactics used in CBBP, as put in Dziubalska-Kołaczyk (2002: Chapter Five). Instead of reusing the actual figures that illustrate the Cluster Spaces in Dziubalska-Kołaczyk (2002), the sections below will use Sonority Sequence Tables drawn upon the defining formulae for one specific type of clusters: double medial clusters. Initial and final clusters, as well as triple medial clusters are left off this article for the sake of brevity.

3.3. Preferred Cluster Spaces

3.3.1. Double medial clusters

3.3.1.1. The formula

Unlike initial and final clusters (see Dziubalska-Kołaczyk 2002), medial clusters are defined with respect to two vowels, and unlike the formulae used for defining initial and finals, where final clusters are subject to a condition that is the mirror image of the one operating over initial clusters, the formula that defines double medial clusters in CBBP is asymmetrical.

The condition for the preferred double initials is defined in CBBP by the following condition,

V1C1C2V2	$\lvert son (V1) - son (C1)\rvert \geq \lvert son (C1) - son (C2)\rvert < \lvert son (C2) - son (V2)\rvert$

(14) The *V1V1V2V2* condition

where “son” stands for the sonority of the given segment (C1, C2, V1, or V2) whose numerical value is taken from the sonority scale given earlier. The condition reads:

"For a word-medial double cluster, the [sonority] distance … between the two consonants should be less than between each of the consonants and its respective neighbouring beat, and it may be equal to the distance between the first consonant and the beat preceding it." (Dziubalska-Kołaczyk 2002: 118)

3.3.1.2. The numbers extracted

The asymmetry of the inequalities used to define preferred medial doubles gives rise to numerical differences in preferred sonority sequence combinations that may serve as preferred medial double consonant clusters.

The *V1C1C2V2* condition yields the following table of CBBP-preferred double medial clusters:

VCCV; CBBP-preferred double medials; C1's in columns, C2's in rows						
	plosive	affricate	fricative	nasal	liquid	semivowel
plosive	+	+	+	+	-	-
affricate	+	+	+	+	-	-
fricative	+	+	+	+	+	-
nasal	-	+	+	+	+	-
liquid	-	-	-	+	+	+
semivowel	-	-	-	-	-	+

(15) VCCV Sonority Sequence Table

The asymmetry of the inequalities used to define preferred double medials (see the *V1C1C2V2* condition above) results in the difference of combinations in respect to sonority sequence of the consonants. Out of 36 technically possible, 21 sonority combinations are preferred under the *V1C1C2V2* condition in CBBP. Among these, 6 combinations have a flat sonority sequence, i.e. they involve two segments of the same manner of articulation, e.g. plosive+plosive or nasal+nasal. Further six combinations are of rising sonority, i.e. the second segment of the cluster being more sonorous than the first one, e.g. plosive+fricative. This leaves as many as 9 combinations of falling sonority, i.e. those in which the second consonant is less sonorous than the preceding one, e.g. nasal+plosive. For the medial doubles sonority shape set, the numbers indicate that there are 1.5 times as many preferred combinations for a falling sonority sequence than for a rising one. There is an equal number of rising and flat sonority sequences. The balance is skewed in that there are

12 non-falling combinations (i.e. flat or rising) opposed to 15 non-rising combinations (i.e. flat or falling). Moreover, there are 15 sloping combinations (i.e. of either falling or rising sonority), while there are only 6 flat sonority sequences to combine.

VCCV; CBBP-preferred double medials; C1's in columns, C2's in rows						
	plosive	affricate	fricative	nasal	liquid	semivowel
plosive	→	↘	↘	↘	∅	∅
affricate	↗	→	↘	↘	∅	∅
fricative	↗	↗	→	↘	↘	∅
nasal	∅	↗	↗	→	↘	∅
liquid	∅	∅	∅	↗	→	↘
semivowel	∅	∅	∅	∅	∅	→

(16) VCCV Sonority Shape Table

The numbers extractable from the VCCV Sonority Shape Table give rise to the following formulations regarding medial double non-beats:

A preferred medial double should not belong in an extended fore binding; out of the 21 preferred medial doubles, 15 have a non-rising sonority shape, as opposed to 6 that have a rising sonority shape; the *no-fore-extended-binding* to *fore-extended-binding* ratio is thus (15/6) = 2.5,

A preferred medial double should not belong in an extended aft binding; out of the 21 preferred medial doubles, 12 have a non-falling sonority shape, as opposed to 9 that have a falling sonority shape; the *no-aft-extended-binding* to *aft-extended-binding* ratio is thus (12/9) = 1.333,

A preferred medial double should not belong in any extended binding at all; out of the 21 preferred medial doubles, 6 have a flat sonority shape, as opposed to 15 that have a non-flat sonority shape; the *no-extended-binding* to *any-extended-binding* ratio is thus (6/15) = 0.4.

Of the three constraints listed above, the weakest one must be subtracted so that the operational set of constraints is not self-contradictory.

Out of the 21 preferred combinations, 15 indicate an underlying primary fore binding that cannot be extended, due to a non-rising sonority shape of the cluster, while an underlying non-extensible primary aft binding is marked by 12 preferred combinations. Hence, the ratio of 1.5 may describe the strength relation between the primary fore binding and the primary aft binding in the preferred-medial-double context.

As regards Right-Hand Alignment, (16) (as well as (15)) shows a 15/6 ratio for keeping the onbeat of the following beat field short, while the offbeat of the preceding beat field shows a ratio of 12/9 for being short irrespectively of Right-Hand Alignment, and is uniformly short in all the 21 preferred sonority sequences when Right-Hand Alignment is operative. The ratios can be calculated from the sonority shapes. A double medial cluster of rising sonority is a context for the onbeat to include both consonants of the cluster in the beat field ({[nnb]}), hence the 9 rising sonority shapes in the above table correspond to two-segment long onbeats. All the remaining preferred medial doubles have a non-rising sonority shape, either flat of falling, thus the onbeat of the following beat field cannot reach beyond the non-beat that directly neighbours on the beat, and the onbeat has to remain no longer than 1 unit ({[nb]}).

Out of the 21 preferred combinations, 9 are of falling sonority, so that a potential 2-unit long offbeat might appear in the preceding beat field ({[bnn]}). The remaining 12 combinations have non-falling sonority shapes, thus the potential offbeat would be short ({-bn]}). However, the numbers are subject to change, since Right-Hand Alignment gives precedence to the following beat, and it is the following beat that decides upon its field's onbeat before the preceding beat may fix its field's offbeat. In syllabic terms, this broadly relates to the Onset-Rhyme approach to the syllable, in which the Onset is given more prominence than the Coda, if the Coda is actually recognised (see Blevins 1995). The operative Right-Hand Alignment would force 9 of the 21 preferred medial double sonority sequences to qualify as two-unit long onbeats of the following beat field, correlating with extended fore bindings between the non-beats of the cluster and the beat. Hence, extended fore bindings and long onbeats are interrelated.

Of the 21 preferred medial double sonority sequence combinations, all contain a primary aft binding, the obvious reason for this being the VC sequence contained within a -VCCV- chain. It is not relevant how many of the preferred combinations allow for an extended aft binding, since in all cases, an extended binding cannot exist where there is no context for a primary binding in the first place. For the same reason, all preferred medial double clusters are subject to a primary fore binding, too. The same set of preferred sonority sequences, however, gives space for only 6 extended fore bindings (for which a cluster of rising sonority is required in the VCCV context). Hence, a numerical weight of the primary aft binding type in comparison to the extended fore binding type is 3.5 if calculated from either the ratio of occurrences (21/ 6), or the ratio of shares (100%/28.571%), the two ratios being equal for the simple reason of the primary aft binding's 100% presence among the sonority sequences in question.

When calculated, the four types of binding give rise to the following ranking: Primary fore bindings {n⟶b} are the strongest, having a ratio of 1.5 against primary aft bindings {b⟵n} as regards the resistance of primary bindings as such to extension (e.g. {(nn)↣b}), and having a ratio of 2.5 against extended fore bindings {(nn)↣b} as regards a fore-primary-binding-specific resistance to extension into extended fore bindings,

Primary aft bindings {b⟵n} are the second strongest, having a ratio of 1.333 against extended aft bindings {b↢(nn)} as regards an aft-primary-binding-specific resistance to extension into extended aft bindings, and having a ratio of 3.5 against extended fore bindings {(nn)↣b} as regards the presence in the preferred VCCV sequences.

The question of which type of the third strongest is a bit more elaborate. If one calculates the strength of primary fore bindings {(nn)↣b} only upon their frequency being related to the frequency of extended aft bindings {b↢(nn)} within the VCCV context alone, the output number is misleading. The VCCV Sonority Shape table above (i.e. (16)) indicates that the fore-to-aft extended binding frequency ratio is 6/9, i.e. 0.666. However, an important point is missing here. Namely, the defining condition for any extended binding is a prior primary binding. Therefore, to calculate the strength of extended bindings, one should also take into consideration that part of extended bindings' strength that stems directly from their relation to primary bindings.

May it be proposed that the strength relation between extended fore and aft bindings be weighted by comparing the frequency of either type of extended bindings against one another, each values being previously multiplied by the strength of the resistance against extension that either type's primary counterpart has. The prerequisite values are as follows. The primary-to-extended weight of fore bindings is 2.5, and the primary-to-extended weight of aft bindings is 1.333. Hence, (6*2.5)/(9*1.333) = 1.25, i.e. when weighted against primary bindings, extended fore bindings are 1.25 times as strong as extended aft bindings, leaving the latter as the weakest type of bindings.

Please notice that the ranking presented herewith is based purely on a mathematical exercise performed on the preferred medial double clusters space in Beats-and-Binding. The spaces for initial and final clusters are irrelevant in this computation, as their formulae are mutually symmetrical. What is left off this article and yet relevant to the matter is the preferred space for medial triple clusters. Again, the formula used in Dziubalska-Kołaczyk (2002: Chapter Five) to define the space is asymmetrical, which allows for checking if primary fore bindings are actually the strongest theory-internally. For space reasons, no actual data from the medial triple clusters portion of the analysis in Michalski (2004) can be presented hereunder, but the reader is kindly asked to take the word that the medial triple space only adds to the conclusion already drawn from the heretofore presented data.

4. Conclusion

Insomuch as the CBBP-preferred medial double cluster context is concerned, the predicted strength-order of bindings has been confirmed. The {n→b} type of binding has been shown to be the strongest in terms of productivity and resistance to transformation, the {b←n} type has been shown to be the second strongest, both {n→b} and {n←b} have been shown to be uniformly stronger than extended {(nn)↣b} and {b↢(nn)} bindings, of which the {(nn)↣b} type has been shown to be the stronger.

5. Final remarks

What has been presented above is but a glimpse of a mathematical exercise performed on a finite-state model. There is no definite claim on how the phonotactic preferences described in Dziubalska-Kołaczyk (2002), and played upon in Michalski (2004) should emerge in particular languages of the world. However, a substantial amount of evidence for Beats-and-Binding being right in its predictions regarding the theory of bindings is given in Dziubalska-Kołaczyk (2002), whereto the reader is hereby referred. As far as the computation performed over Beats-and-Binding is concerned, the reader is referred to Michalski (2004), where detailed analyses of each CBBP-Preferred Cluster Space is provided, together with a short theory of segment-to-segment sonority increments, plus dozens of numbers extracted from Sonority Sequence Tables under virtually every condition phonologically viable. In particular, the paper in question may appear interesting for its take on CBBP's Preferred Cluster Spaces for triple medial clusters, which actually had the biggest impact on the calculations performed therein, but which were left off this article for space reasons.

References:

Aronoff, M. and R. T. Oehrle. (eds.). 1984. *Language Sound Structure. Studies in Phonology Presented to Morris Halle by His Teacher and Students.* Cambridge, Mass.: The MIT Press.

Bertacca, A. (ed.). 2005. *Historical Linguistic Studies of Spoken English*. Pisa: PLUS (Pisana Libraria Universitatis Studiorum). Pisa University Press.

Blevins, J. 1995. Syllable in Phonological Theory. In: J.A. Goldsmith (ed.). 206-244.

Dziubalska-Kołaczyk, K. 1995. *Phonology without the Syllable. A Study in the Natural Framework.* Poznań: Motivex.

Dziubalska-Kołaczyk, K. 2002. *Beats-and-Binding Phonology*. Frankfurt a.M.: Peter Lang.

Dziubalska-Kołaczyk, K. 2005. "Phonotactics of consonant clusters in the history of English." In: A. Bertacca (ed.). 15-34.

Goldsmith, J.A. (ed.). 1995. *The Handbook of Phonological Theory.* Oxford: Blackwell.

Gussmann, E. 2002. *Phonology. Analysis and Theory*. Cambridge: Cambridge University Press.

Hammond, M. 1999. *The Phonology of English. A Prosodic Optimality-Theoretic Approach*. Oxford: Oxford University Press.

van der Hulst, H. and N.A. Ritter. 1999a. "Theories of the syllable". In: H. van der Hulst and N.A. Ritter. (eds.). 1999b. 13-52.

van der Hulst, H. and N.A. Ritter. (eds.). 1999b. *The Syllable. Views and facts*. Berlin: Mouton de Gruyter.

Maddieson, I. 1999. "In search of universals". *ICPhS 99*. vol.3: 2521-2528.

Michalski, G. 2004. Phonotactic preferences as evidence for binding. Variation on Beats-and-Binding Phonology. Unpublished M.A. thesis. Adam Mickiewicz University, Poznań.

Scheer, T. 2004. *A Lateral Theory of Phonology. What is CVCV, and why should it be?* Berlin: Mouton de Gruyter.

Selkirk, E. 1984. "On the Major Class features and Syllable Theory". In: M. Aronoff and R.T. Oehrle. (eds.). 107-136.

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