CHAPTER 2

A THEORY OF POSITIONAL AUGMENTATION CONSTRAINTS

2.1 Introduction

As outlined in Chapter 1, a successful theory of markedness constraints that apply exclusively to phonologically strong positions (**M/str** constraints) must be able to predict which markedness constraints have **M/str** counterparts and which do not. The proposal developed here is that the distinction between legitimate, attested **M/str** constraints and problematic, unattested **M/str** constraints is made on substantive grounds, involving factors such as perceptual prominence and the way in which certain strong positions are involved in word recognition. As a consequence, a theory of **M/str** constraints must be seen in the context of a broader question: how it is that substantive restrictions can affect the phonological system.

This chapter, which lays out the theoretical framework within which the analysis of phonological requirements for strong positions is to be developed, therefore addresses three main topics. First, §2.2 presents a general theory of the interaction between substantive grounding and the formal grammar: the Schema/Filter model of the universal constraint set CON. An explicit formal treatment of relativized (position-specific) constraints is also developed, under which the formulation of a relativized constraint such as ONSET/σ́ is compositionally derived from the formulation of the corresponding general constraint.

The next two sections then apply the framework developed in §2.2 to the specific case of **M/str** constraints. §2.3 is concerned with the crucial relationship between **M/str** constraints and perceptual prominence. In §2.3.1, the Prominence Condition, which screens potential **M/str** constraints to ensure that they are built from augmentation (prominence-enhancing) constraints, is implemented as one of the filters in the Schema/Filter model. In §2.3.2, a number of augmentation constraints are examined. For each constraint, the nature of its relationship to perceptual prominence is discussed and an explicit constraint formulation is given. §2.3.3 enumerates the **M/str** versions that are predicted to exist for each augmentation constraint, given the approach to relativized constraints developed in §2.3.1.2 and the size of the element that serves as the focus of the **M** constraint in question. The inventory of predicted **M/str** constraints is then compared to the inventory of attested **M/str** constraints from the case studies in chapters 3 and 4.

Then, §2.4 discusses the substantive pressures that specifically affect markedness constraints for psycholinguistically strong positions (**M/Ψstr** constraints) because these positions derive their special status from their importance in early-stage word recognition. The substantive pressures in question are implemented in the model as a second constraint filter, the Segmental Contrast Condition. This filter disallows even augmentation constraints from being relativized to psycholinguistically strong positions if they would call for excessive neutralization of contrasts that are relevant for early-stage word recognition (§2.4.1). The differences between phonetically and psycholinguistically strong positions, and other domains of phonology in which these differences are potentially relevant, are addressed in §2.4.2.

Finally, conclusions and implications are discussed in §2.5.

2.2 Formal models of constraints and CON

Research in the framework of OT attempts to explain phonological phenomena by means of a set of ranked and violable constraints. But in order for phonological analyses to be as constrained, and thus as predictive, as possible, there must be a theory of what constitutes a well-formed or legitimate constraint.

Here, the empirical focus is those phonological requirements that specifically target phonetically and psycholinguistically strong positions; such requirements are to be analyzed by means of **M/str** constraints, as outlined in §1.3.2. However, a theory of possible and impossible **M/str** constraints can only be developed in the context of a general theory of the nature of constraints and the universal constraint set.

This section presents two components of a general theory of constraints. First, the Schema/Filter model of CON, a theory of the influence of substantive considerations on the formal phonological system, is proposed in §2.2.1. Then, an explicitly compositional treatment of position-specific constraints — in other words, an account of what it means to have constraints that are relativized to particular positions, and how such constraints are related to their context-free counterparts — is presented in §2.2.2. The Schema/Filter model and the compositional approach to relativized constraints are both integral parts of the theory of possible and impossible **M/str** constraints that is developed in later sections of this chapter.

2.2.1 The Schema/Filter model of CON

This subsection presents the Schema/Filter model of the universal constraint set CON, a model of how substantive considerations affect the nature of the constraint set. For example, as outlined in §1.2, there is a substantive restriction on **M/str** constraints, stated informally as in (1) (see §2.3.1 for a more detailed discussion of this restriction).

(1) *The Prominence Condition*

> Markedness constraints specific to strong positions are included in CON only if the general markedness constraints from which they are built call for the presence of perceptually prominent properties.

However, an important question arises when a restriction like the Prominence Condition is proposed. How can a statement about which constraints are or are not included in CON be implemented as part of the theory of grammar rather than as an extragrammatical observation?

This question is actually part of a more general problem concerning the nature of Con. Namely, why do certain constraints exist, when others, although built from the same set of phonological elements combined in the same ways, do not? For example, Eisner (1997) observes that a theory that builds constraints from primitive elements, and is able to generate the familiar constraints Onset ('Syllables have onsets; syllables are left-aligned with C') and NoCoda ('Syllables lack codas; syllables are right-aligned with V'), also generates the converse constraints "NoOnset ('syllables are left-aligned with V')" and "Coda ('syllables are right-aligned with C')", which are not part of Con (Prince & Smolensky 1993). Something must ensure that Onset and NoCoda are existing constraints, while "NoOnset" and "Coda", although they are formally possible constraints, do not in fact exist. Fukazawa & Lombardi (2000) raise similar questions about the use of constraint conjunction to derive complex constraints.

Hayes (1999a) considers this problem with respect to articulation-based markedness constraints,[1] comparing attested and phonetically plausible constraints like *NC̥ (*[+nas][-voi]; Pater 1996, 1999) with implausible and unattested constraints like "PostSonorant-Devoicing (*[+son][+voi])". Hayes proposes that all logically possible constraints of this sort, which ban particular features in particular environments, are evaluated by a principle known as Inductive Grounding. Essentially, a constraint passes the inductive-grounding requirement if it partitions the phonetic space into "easy" and "difficult" articulations more accurately than constraints of equal or greater formal simplicity do. *NC̥ is inductively grounded, while "PostSonorant-Devoicing" is not, so only the former is included in Con.

The Schema/Filter model of Con developed here expands on Hayes' (1999a) proposal that knowledge of articulatory or perceptual difficulty can be used to distinguish between certain kinds of possible and impossible constraints. The Schema/Filter model is a constraint "metagrammar" consisting of two components: a set of constraint schemas, which are functions that apply to arguments (primitive phonological elements) in order to construct individual constraints; and a set of constraint filters, which make use of articulatory, acoustic, perceptual, and other substantive information to distinguish between legitimate and impossible constraints. The Schema/Filter model is summarized in (2).

(2) The Schema/Filter model of Con: a constraint metagrammar

Free constraint construction (**schemas** × **arguments**)	➜	Substantive **filters** block certain potential constraints	➜	Con

Constraint schemas and constraint filters are discussed in §2.2.1.1 and §2.2.1.2 respectively.

[1] Hayes (1999a) proposes that Inductive Grounding is relevant for constraints that are perceptually grounded, as well as those that are articulatorily grounded. However, the example that he discusses in detail is an articulatory case.

Once the Schema/Filter model has been developed in this section, its relevance to the specific question of **M/str** constraints is demonstrated in subsequent sections. Namely, the Prominence Condition (1) is incorporated into the constraint metagrammar as a filter on **M/str** constraints (§2.3). Likewise, the Segmental Contrast Condition, which places additional restrictions on augmentation constraints for psycholinguistically strong positions beyond those imposed by the Prominence Condition, is implemented as a constraint filter on **M/Ψstr** constraints (§2.4).

2.2.1.1 Constraint schemas

It would be logically possible to view the universal constraint set CON as an arbitrary collection of unitary, unanalyzable constraints that is supplied by Universal Grammar. However, there are several reasons for preferring a conception of CON in which constraints are constructed from more basic elements. For one thing, constraints that refer to individual morphemes in a language (such as alignment constraints that cause particular morphemes to be prefixes or suffixes) cannot possibly be included in Universal Grammar in their final form, since they include language-specific information. Thus, there must be a process of constraint construction for at least some constraints (as when the universally available Generalized Alignment schema is applied to individual morphemes in a given language; McCarthy & Prince 1993a). Even many plausibly universal constraint families, such as the IDENT[*F*] family or the *[*F*,*G*] family (where *F* and *G* are variables that stand for phonological features), are transparently composed of a general constraint schema applied to a number of elements of a particular type (Smolensky 1995) — in these two cases, features — and furthermore, the formulation of each of the resulting constraints in the family (e.g., *[-son$_F$, +voi$_G$]: '[-son]$_F$ and [+voi]$_G$ must not co-occur in the same segment') is completely predictable. To ignore such regularity would be to miss a generalization. Moreover, assuming that the contents of CON are universally supplied as-is would make it more difficult to integrate substantive grounding into the theory of grammar. One could say only that the constraints included in CON happen to be those that are substantively grounded; substantive considerations would play no active role in shaping CON.

For these reasons, the approach to CON taken here is the Schema/Filter model. As outlined above (see (2)), one component of this model is a constraint-construction module in which all formally possible constraints are constructed from the combination of a set of constraint schemas, which are modeled as functions, and a set of primitive phonological elements that serve as arguments for the schemas (including a set of strong positions to which general constraints can be relativized).[2]

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[2]Other proposals to treat the constraint set as a system built up from a set of basic elements include Eisner (1997), who proposes that many OT constraints can be recast in terms of two primitive relations between phonological elements, 'temporally overlaps' and 'does not temporally overlap'; and analyses that view various constraint types as built from other, simpler constraints through constraint conjunction (including Smolensky 1995, 1997; Zoll 1998).

The concept of a constraint schema has its origin in the Generalized Alignment treatment of alignment constraints (McCarthy & Prince 1993a), shown in (3). (See also Smolensky 1995 on "parametrized families" of constraints and Suzuki 1998 on a schema for OCP constraints.)

(3) The ALIGN schema (Generalized Alignment; McCarthy & Prince 1993a:80)

ALIGN(*Cat*1, *Edge*1, *Cat*2, *Edge*2)
$\forall$ *Cat*1 $\exists$ *Cat*2 such that *Edge*1 of *Cat*1 and *Edge*2 of *Cat*2 coincide

where *Cat*1, *Cat*2 $\in$ *PCat* $\cup$ *MCat* (i.e., prosodic and morphosyntactic categories)
*Edge*1, *Edge*2 $\in$ {R(ight), L(eft)}

The ALIGN schema applies to edges and grammatical categories to create individual alignment constraints, such as ALIGN(Root, L, PrWd, L) in (4) (where PrWd = Prosodic Word).

(4) ALIGN(Root, L, PrWd, L)
$\forall$ Root $\exists$ PrWd such that Edge=L of Root and Edge=L of PrWd coincide

Note that the formulation of the constraint ALIGN(Root, L, PrWd, L) is completely compositional, given the formulation of the ALIGN schema and the choice of *Cat*(egorie)s and *Edge*s used in building this particular alignment constraint.

This approach to forming specific constraints out of general constraint types is generalized in the Schema/Filter model, where all constraints are built by applying schemas to arguments. For example, there is an IDENT schema of the form IDENT-*Corr*[*Feat*], with the following formulation.

(5) The IDENT schema

IDENT-*Corr*[*Feat*]	If S_1 and S_2 are strings related by the correspondence relation[3] *Corr*, $\alpha \in S_1$, $\beta \in S_2$, and $\alpha \Re \beta$, then α and β agree in their specifications for the feature *Feat* (I.e., "corresponding segments in the *Corr* relation have identical specifications for *Feat*." On IDENT constraints and correspondence theory, see McCarthy & Prince 1995.)

[3]The set of possible correspondence relations over which faithfulness constraints can be defined includes the I(nput)-O(utput), O(utput)-O(utput), and B(ase)-R(eduplicant) relations (McCarthy & Prince 1995; Benua 1995, 1997; Burzio 1994, 1997).

Thus, any individual IDENT constraint that is built from this schema has a formulation that is compositional, given the formulation of the schema and the specific choice of arguments for the *Corr* and *Feat* variables.

Another example of a constraint schema is the general schema for positional constraints, both markedness (**M/str**) and faithfulness (**F/str**),[4] as in (6). (This schema is discussed in more detail in §2.2.2 below.)

(6) The **C**/*str* schema

C/*str* For all *y*, if *y* is a *str*, then **C** holds of *y*

where *y* is an element in the focus of the constraint **C**
(see §2.2.2 for elaboration)

The schemas and the constraints that they build must be divided into the categories **M** and **F**, so that filters can make reference to either markedness or faithfulness constraints — for example, the Prominence Condition is a filter that specifically applies to **M/str** constraints (and not to, say, **F/str** constraints). However, the labels **M** and **F** need not be independently stipulated, because they can be derived from the content of the schema formulations themselves. Any schema or constraint that makes reference to a correspondence relation is **F**, and all others are **M**.

In addition to a set of constraint schemas, the constraint-construction module also contains a set of primitive phonological elements, which serve as the arguments for the variables in the schemas. These include, for example, the set of phonological features *Feat*, the set of edges *Edge*, the set of correspondence relations *Corr*, and the set of prosodic constituents *PCat*. Another set of primitive elements in the Schema/Filter model is the set of strong positions *str* to which constraints can be relativized. The set of strong positions is further subdivided into the set of phonetically strong positions *Φstr* and the set of psycholinguistically strong positions *Ψstr*; this division is necessary because some filters, including the Segmental Contrast Condition (§2.4), are sensitive to the difference between *Φstr* and *Ψstr* (see also §2.4.3 for another example of a filter that is sensitive to this difference).

It should be emphasized that the strong positions included in the sets *Φstr* and *Ψstr* are formal phonological objects — they derive their special status from their characteristic phonetic or psycholinguistic salience, but they are not supplied directly by the phonetic or the psycholinguistic component of the grammar. This must be the case, as two examples will

[4]The use of a general **C**/*str* schema here, rather than a more specific **M**/*str* schema, assumes that the constraints responsible for positional neutralization effects (that is, contrast preservation specifically in strong positions) are **F/str** constraints; see §5.2 for a discussion of alternatives.

illustrate. First, phonetically strong positions typically have special status because they possess salient cues to the recovery of particular contrasts (§2.4.3). However, a positional augmentation (**M/str**) constraint can make reference to a phonetically strong position even when the force of the general **M** constraint from which **M/str** is built has no relationship to the featural contrast for which the position has special salient cues. E.g., the special feature-licensing abilities of the phonetically strong position stressed syllable are apparently limited to vowel features and suprasegmentals like tone (§2.4.3), but augmentation constraints like ONSET and the *ONSET/X subhierarchy, which manipulate *consonantal* features, can nevertheless be relativized to the position stressed syllable (§3.2). Thus, the status of the stressed syllable as a strong position is more abstract and general than the phonetic origin of that privileged status.

A second example of why the strong positions must be treated as abstract formal objects is seen in the designation of the initial syllable as a psycholinguistically strong position. This position has special status because material toward the beginning of the word has a particularly large influence on early-stage word recognition (see §4.3.2 for detailed discussion). But while the psycholinguistic importance of material in a word seems to fall off gradually from left to right, the phonological reflection of this importance is categorical; the initial syllable is a privileged position, but there is no sense in which, for example, the third syllable has special phonological status compared to the fourth.

An open question at this point is the ultimate source of the basic elements of the system: the schemas and their arguments. Some of them may be innate, part of UG. However, at least some of these fundamental phonological elements may be learned as part of the process of child language acquisition. See, for example, Hayes (1999ab) and Boersma (1998) for proposals concerning ways in which aspects of the constraint set might be learnable.[5]

To summarize, the constraint-construction module of the Schema/Filter model of CON has the following properties. Any constraint schema can apply to any argument, as long as it is of the appropriate type (i.e., a feature must replace a *Feat* variable, and cannot replace *Edge* or *Corr* or *PCat*). Also, any constraint, whether **M** or **F**, can be relativized to any member of the set

[5]A related question is this: Are the constraints literally constructed from the schemas as part of the language acquisition process (Hayes 1999a, Boersma 1998)? Or does the notion of "constraint construction" apply at a more abstract level, so that the analysis of the constraint set into schemas, arguments, and filters is simply a descriptive model or, perhaps, an evolutionary model? The former hypothesis is more attractive, in that it reduces the amount of phonological knowledge that would have to be innate, while still allowing for CON to be universal. At the very least, as noted above, alignment constraints that refer to specific morphemes or morpheme classes in a language must be actively acquired by means of the generalizable ALIGN schema, because information about individual morphemes cannot be innate.

of strong positions.[6] Crucially, other than argument/variable type-matching, there are no restrictions at this stage. Thus, all formally possible constraints are constructed by the constraint metagrammar, including constraints that are not empirically attested — but this "overgeneration" of constraints is corrected by the filter module, discussed in the following subsection.

Thoroughly defending the claim that every constraint in the universal inventory is constructed from some schema is beyond the scope of this dissertation. It may be the case that a few constraints that are not decomposable into schemas and arguments are also supplied by UG and appear in CON. However, any constraint that is a member of a family of constraints, including those mentioned above and a number of others as well (**Feat*; MAX-*Corr-PCat*; ....), is best viewed as the output of a schema. Most important for now is the fact that the Schema/Filter model provides an explicit framework within which the nature of the constraints in CON can be investigated. Furthermore, this system has a number of desirable characteristics. It reduces to a set of universal primitives (the schemas and their arguments). Moreover, as with ALIGN(Root, L, PrWd, L) in (4) above, constraint formulations become transparently compositional, given the formulation of the schema from which each constraint is built.

2.2.1.2 Constraint filters

The preceding subsection has shown that it is advantageous to develop a model of CON in which constraints are constructed from a set of basic elements. However, any such theory must also be able to handle the problem of formally possible constraints that nevertheless do not exist. The Schema/Filter model of CON addresses this problem with a set of constraint *filters*. Constraint filters make use of substantive information to block constraints that are formally possible (and thus are emitted by the constraint-construction module), but are not appropriate constraints on substantive grounds.

As the discussion in §1.2 has shown, the difference between formally possible **M/str** constraints that exist and those that do not is a matter of whether or not the **M/str** constraint in question satisfies certain substantive requirements: any **M/str** constraint must be an augmentation (prominence-enhancing) constraint, and if it is an **M/Ψstr** constraint, its satisfaction must not entail the loss of a crucial phonological contrast.

More generally, there are many cases in which a formally possible constraint — one that has the same formal structure as a constraint that is empirically attested — does not exist, but its nonexistence is understandable on substantive grounds. For example, given the FEATCO-OCCUR

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[6]There is a general condition on relativized constraints that rules out any **C**/*str* constraint in which the domain of application of **C** is larger than, or otherwise incompatible with, the size of the strong position in question. For example, the **M/str** constraint HAVECPLACE/Vː is ruled out because HAVECPLACE is evaluated within the domain of a consonant (see §2.3.2.4 below), and there is no consonant contained within the strong position Vː (long vowel). See §2.2.2 and §2.3.3 for further discussion of such cases of domain mismatch.

schema and the set of features shown in (7), both the attested constraints in (8a) and the unattested constraints in (8b) can be constructed.

(7) (a) FEATCO-OCCUR schema: *[$Feat_1$, $Feat_2$]

(b) *Feat* ∈ {±son, ±hi, ±voi, lab, RTR, ATR, ...}

(8) Formally possible FEATCO-OCCUR constraints

(a) Attested FEATCO-OCCUR constraints

*[-son, +voi] (Westbury & Keating 1986; Stevens & Keyser 1989)
*[+hi, RTR] (Archangeli & Pulleyblank 1994)

(b) Unattested FEATCO-OCCUR constraints

*[+son, lab]
*[+hi, ATR]

Thus, an adequate model of CON must be able to exclude the constraints in (8b).[7]

The difference between the actual constraints in (8a) and the formally possible, but nonexistent, constraints in (8b) is that the former are functionally grounded in the sense of Archangeli & Pulleyblank (1994) — there are articulatory and/or perceptual reasons why constraints such as these should exist. For example, the existence of the constraint *[-son, +voi] reflects the fact that voiced obstruents are articulatorily more difficult (Westbury & Keating 1986), and perceptually less distinct (Stevens & Keyser 1989), than voiceless obstruents or voiced sonorants. Similarly, since the feature [+high] involves an upward and forward movement of the tongue body, which lowers F1, while the feature [RTR] involves a downward and backward movement of the tongue root, which raises F1, the constraint *[+hi, RTR] also reflects articulatory difficulty and conflicting auditory cues. But feature pairs that are articulatorily and perceptually unrelated, like [+sonorant] and [labial], or mutually enhancing, like [+high] and [ATR], do not combine to form legitimate feature co-occurrence constraints.

The principle of Inductive Grounding proposed by Hayes (1999a) provides a way to distinguish between the constraints in (8a) and those in (8b). Inductive Grounding ensures that a

[7]This problem must be addressed in any model of CON. The current proposal makes it easy to see that a constraint like *[+hi, ATR] is predicted to exist and must somehow be ruled out, because the model explicitly includes a general FEATCO-OCCUR constraint-building schema. However, the question of why there is a constraint *[+hi, RTR] and not a constraint *[+hi, ATR] is independent of the choice of a model that postulates constraint schemas.

constraint of the FEATCO-OCCUR type (as well as similar kinds of constraints, such as constraints on the featural context in which a particular segment can occur) is part of CON only if segments or sequences that violate the constraint are more difficult, articulatorily (or perceptually), than segments or sequences that satisfy it.[8] The unattested constraints in (8b) fail this filter; for *[+son, lab], the segments that violate the constraint are no more phonetically difficult than those that satisfy it, and for *[+hi, ATR], the results are completely wrong, since segments that violate this constraint are phonetically *better* than (a subset of) those that satisfy it. On the other hand, the FEATCO-OCCUR constraints in (8a) pass Inductive Grounding, so they are included in CON.

Hayes (1999a) observes that there is an important consequence of the use of the principle of Inductive Grounding to determine which FEATCO-OCCUR constraints are part of CON and which are not. Namely, this approach provides a way for functional grounding to have a major impact on the constraint system, rather than merely being some kind of extragrammatical description of the system — while still allowing for a formal theory of phonology, which accounts for the fact that many phonological phenomena are categorical, reflect phonological constraints that are logically simple in structure, and involve classes or sets of elements defined over somewhat abstract, if often phonetically based, properties.

The Schema/Filter model of CON extends Hayes' (1999a) approach, resulting in a general model of how substantive grounding can shape the phonological system. In this model, the output of the constraint-construction module, which consists of all formally possible constraints, passes through a set of constraint filters (see (2) above). The filters determine which of the formally possible constraints are in fact included in CON. The set of constraint filters includes the Inductive Grounding Principle of Hayes (1999a) and also filters instantiating all other substantively based restrictions that hold of the constraints in CON. Thus, two of the constraint filters in the system are the Prominence Condition on **M/str** constraints (§2.3) and the Segmental Contrast Condition on **M/Ψstr** constraints (§2.4). (Another possible filter, that restricts positional faithfulness constraints for phonetically strong positions (**F/Φstr**), is considered in §2.4.3 below.)

In this model, it is a characteristic of all constraint filters that, like the Inductive Grounding Principle, the Prominence Condition, and the Segmental Contrast Condition, they make use of information from outside the formal phonological system to determine which of the formally possible constraints are actually included in CON. Thus, the constraint filters are the point of intersection between the formal phonological system and substantive or functional considerations. The articulatory phonetics, the perceptual system, the language processor, and other such sources of functional influence do not create constraints. However, through the constraint filters, these systems have what amounts to veto power over the formal constraints that

[8]See Hayes (1999a) for further discussion of the principle of Inductive Grounding, which also takes into account the formal simplicity of the constraints being evaluated: a constraint passes Inductive Grounding if it makes a better partition of the phonetic space into "easy" and "difficult" than any constraint of *equal or greater formal simplicity*.

are created. As a result, the structure of CON reflects substantive and functional concerns even though it contains only objects created by a formal system.[9]

In the case of **M/str** constraints, the **C/***str* constraint schema allows any markedness constraint to be relativized to any strong position, because all that a schema does is to apply its function to any and all relevant arguments (here, to constraints — including markedness constraints — and strong positions). Functional grounding enters the picture in the form of the constraint filters, in this case, the Prominence Condition and the Segmental Contrast Condition. (The kinds of substantive information that are relevant for these filters, and the way in which constraints are tested for compliance with the filters, are discussed in §2.3 and §2.4.)

The Schema/Filter model thus operates as in (9).

(9) The Schema/Filter model of CON, with example constraints

	Free constraint construction (**schemas** × **arguments**)	➜	Substantive **filters** block certain potential constraints	➜	CON
(a)	*[$Feat_1$][$Feat_2$] × [+hi], [ATR], [RTR] ... (after Archangeli & Pulleyblank 1994)		~~*[+hi, ATR]~~, *[+hi, RTR] ...		*[+hi, RTR] ...
(b)	**M**/*str* × *MIDV, HEAVYσ/σ́ ...		~~*MIDV/σ́~~, HEAVYσ/σ́ ...		HEAVYσ/σ́ ...

Constraint schemas are free to apply to all arguments of the correct type. If the output of a particular schema has no associated filters, then all formally possible constraints built from that schema will be included in CON, and there will be no distinction between constraints of that type that are somehow substantively grounded and constraints of that type that are not.[10] However, for many constraint types, such as FEATCO-OCCUR constraints or **M/str** constraints, there are substantive filters that pass only a subset of the possible constraints. Thus, the universal constraint set CON is shaped by formal considerations, because all constraints are built from a

[9]For other approaches to the functional grounding of constraints and/or phonological processes, see, e.g., Steriade (1993, 1997, 1999ab), Archangeli & Pulleyblank (1994), Flemming (1995), Ní Chiosáin & Padgett (1997), Boersma (1998), and Pater (1999). For another use of the perceptual system to evaluate phonological alternatives, see the targeted constraints of Wilson (2000, 2001).

[10]This may be the case for (non-positional) faithfulness constraints, since **F** constraints demand the preservation of input characteristics (rather than structural well-formedness).

basic phonological inventory of schemas and arguments, and substantive considerations, because for certain constraint types there are filters encoding extraphonological, substantive information that determine which of the formally possible constraints are ultimately part of CON.

The question of how **M/str** constraints, in particular, are affected by constraint filters is taken up in §2.3 and §2.4 below. First, however, there is one more general theoretical point about constraints to be addressed: how the formulation of a relativized or position-specific constraint (such as an **M/str** constraint) is to be derived, compositionally, from the formulation of the general version of the constraint. This question, which has crucial implications for determining which **M/str** constraints can legitimately be relativized to which positions, is the topic of the following section.

2.2.2 A compositional approach to relativized constraints

One of the advantages of a system in which constraints are built from general constraint schemas is that the formulation of each specific constraint becomes predictable from the formulation of the general schema used to construct the constraint in question, plus the semantic contributions of the specific arguments that fill the variables in the schema. For example, the formulation of the individual alignment constraint in (10b) is transparently related to the formulation of the general ALIGN schema in (10a) plus the arguments *Cat*1=Root, *Cat*2=PrWd, *Edge*1=L, and *Edge*2=L (schema and constraint repeated here from (3), (4) above).

(10) The compositional formulation of alignment constraints

(a) The ALIGN schema (adapted from McCarthy & Prince 1993a:80)

ALIGN(*Cat*1, *Edge*1, *Cat*2, *Edge*2)
$\forall$ *Cat*1 $\exists$ *Cat*2 such that *Edge*1 of *Cat*1 and *Edge*2 of *Cat*2 coincide

where *Cat*1, *Cat*2 $\in$ *PCat* $\cup$ *MCat*
*Edge*1, *Edge*2 $\in$ {R(ight), L(eft)}

(b) An individual example of an alignment constraint

ALIGN(Root, L, PrWd, L)
$\forall$ Root $\exists$ PrWd such that Edge=L of Root and Edge=L of PrWd coincide

Descriptively, **M/str** constraints are formed by relativizing a markedness constraint to a strong position. Under the Schema/Filter model of CON, this means that there is a constraint schema, the **C**/*str* schema, that takes a constraint and relativizes it to one of the elements in *str*, the set of strong positions. This constraint schema is defined as in (11).

(11) The **C**/*str* schema

C/*str* For all *y*, if *y* is a *str*, then **C** holds of *y*

where *y* is an element in the focus of the constraint **C**

The **C**/*str* schema functions as a general schema that can relativize any constraint to any strong position, while still compositionally generating a meaningful formulation for the relativized constraint, because it makes crucial reference to the focus of the constraint that it takes as one of its arguments. The concept of a constraint focus is developed by Crowhurst & Hewitt (1997), who describe it as follows and formalize it as in (12).

> ...every constraint has a FOCUS, which may be defined as the linguistic object upon which some condition of maximum harmony is predicated. Abstracting away from differences due to style, we recognize at the heart of any constraint a definition of a state of maximum harmony holding on some linguistic object in relation to some other linguistic object. (Crowhurst & Hewitt 1997:9)

(12) The focus of a constraint (Crowhurst & Hewitt 1997:10)

i. Every constraint has a unique focus.
ii. A constraint's focus is identified by the universally quantified argument.

Thus, for every constraint, a constraint focus can be identified. The **C**/*str* schema takes advantage of this universal fact about constraint formulations. This schema embeds the formulation of any general constraint **C** inside an *if-then* statement, such that if a particular element from the focus of **C** is an instance of a chosen strong position, then **C** must hold of that element — but if the element under scrutiny is not an instance of the strong position in question, then, as desired, the positional constraint is vacuously satisfied whether **C** actually holds of that element or not.

For example, consider the **M/str** constraint ONSET/σ́ (§3.2.2), a positional version of ONSET that is relativized to the strong position stressed syllable. The general constraint ONSET has the formulation in (13) (see §2.3.2.3.2 for discussion), requiring the head (peak) of a syllable to be preceded by something else in the syllable.

(13) ONSET For all syllables *x*, $a \neq b$

where *a* is the leftmost segment dominated by *x*
b is the head of *x*

The focus of any constraint is the element associated with universal quantification, so in the case of ONSET, the focus is the syllable.

When ONSET becomes an argument of the **C**/*str* schema, repeated in (14), along with a designated strong position, such as σ́, the positional constraint in (15) is the result.

(14) **C**/*str* For all *y*, if *y* is a *str*, then **C** holds of *y*
where *y* is an element in the focus of the constraint **C**

(15) ONSET/σ́ For all syllables *x*, if *x* is a σ́, then $a \neq b$
where *a* is the leftmost segment dominated by *x*
b is the head of *x*

In some cases, a positional constraint built from the **C**/*str* schema will be anomalous, because the strong position to which the constraint is relativized is not the same kind of unit as that found in the focus of the constraint. One such example is ONSET/Vː (16), a version of ONSET relativized to the strong position long vowel.

(16) ONSET/Vː For all syllables *x*, if *x* is a Vː, then $a \neq b$
where *a* is the leftmost segment dominated by *x*
b is the head of *x*

This positional constraint is well-formed with respect to the constraint schema **C**/*str*, which simply combines constraints and strong positions. However, it is a meaningless constraint, because a syllable and a long vowel are distinct classes of phonological objects. Informally, it is meaningless to require that a long vowel have an onset, since it is syllables, not vowels themselves, that have onsets. Formally, the problem is that the antecedent clause in (16), 'if [syllable] *x* is a Vː', will always be false; a conditional with an antecedent that is false is itself always true, so a constraint such as ONSET/Vː will be (vacuously) satisfied by every output candidate. By definition, a constraint like this will never be 'active' on a candidate set — that is, it will never demarcate a proper subset of the candidate set as suboptimal (Prince & Smolensky 1993).

The anomaly that arises when the focus of a constraint is a different class of object from the strong position to which the constraint has been relativized will be called a *domain mismatch*. For the sake of explicitness, relativized constraints involving a domain mismatch are assumed not to be included in CON; i.e., there is assumed to be a constraint filter that screens them out. However, nothing crucial hinges on this assumption, because even if such constraints were included in CON, they would simply have no effect on the selection of optimal output forms in any language.

In §2.3.2 below, a number of markedness constraints that have **M/str** counterparts are discussed. Explicit formulations are given for each markedness constraint. As outlined here, it is the nature of the focus of each constraint that determines the strong positions to which it can be meaningfully relativized, as opposed to those positions that lead to a domain mismatch.

2.2.3 Summary

This section has laid out several aspects of a general theory of constraints within which the subsequent discussion of **M/str** constraints can be carried out. First, the question of how substantive considerations affect the universal constraint set was addressed. In the Schema/Filter model of CON, constraints are built from basic phonological elements (such as features and prosodic constituents) according to a set of constraint schemas. All formally possible combinations of schemas and the basic elements that serve as their arguments can be constructed. However, there are substantive filters that operate on the output of constraint construction, allowing only some of the formally possible constraints to be included in CON. The advantage of the Schema/Filter model is that it provides a way for phonology (that is, CON, and therefore also individual language-particular constraint rankings) to be influenced and shaped by functional or substantive considerations, while remaining a formal system that manipulates formal objects in a constrained way.

In the Schema/Filter model, it is constraint schemas that determine, compositionally, the formulations of the individual constraints that they construct. In other words, every constraint built from a particular schema has a formulation that is predictable from the formulation of the schema plus the phonological elements involved in the specific constraint. Therefore, a general theory of **M/str** constraints must provide a way for the formulation of every **M/str** constraint to be compositionally determined from the formulation of the general markedness constraint and the particular strong position to which the constraint has been relativized. This is accomplished by defining the **C**/*str* schema — the schema responsible for relativized constraints — so that it embeds the original formulation of a general constraint **C** into an *if/then* clause that is sensitive to the focus of the general constraint: if the focus of **C** is an instance of *str*, then the property demanded by **C** must hold.

2.3 M/str constraints and the Prominence Condition

Now that a general model of constraints, constraint formulations, and the structure of CON has been laid out, a theory of positional augmentation constraints can be developed within this framework. The first component of such a theory is the Prominence Condition — the restriction of **M/str** constraints to those that enhance the perceptual prominence of the strong position to which they are relativized. In §2.3.1, the Prominence Condition is formally modeled as one of the filters in the Schema/Filter model. Then, §2.3.2 demonstrates that the predictions made by the Prominence Condition as a filter on **M/str** constraints are correct: the individual markedness constraints that are observed to have **M/str** counterparts are all shown to be augmentation (prominence-enhancing) constraints. Finally, §2.3.3 considers what happens when the general augmentation constraints discussed in §2.3.2 are relativized to the various strong positions, showing which positional augmentation constraints are meaningful constraints and which give rise to a domain mismatch.

2.3.1 The Prominence Condition and enhancement of perceptual prominence

In many languages, such as those discussed in chapters 3 and 4, there are phonological requirements enforced specifically of strong positions. For example, in Mohawk (§3.2.1.1), stressed syllables, but not other syllables, are required to be heavy. In Chamicuro (§3.4), onsets, but not other consonants, are required to have supralaryngeal Place specifications. In Arapaho (§4.2.1.1), initial syllables, but not other syllables, are required to have onsets. Such effects are observed in a language when a high rank is assigned to **M/str** constraints, markedness constraints that specifically refer to strong positions (§1.3.2). However, as demonstrated in §1.2, there are formally possible **M/str** constraints that do not exist, such as *MIDV/σ́, a constraint that would ban mid vowels in stressed syllables. Therefore, a theory of **M/str** constraints must predict which of the formally possible **M/str** constraints are actually attested.

The proposal developed here is that **M/str** constraints are restricted by the Prominence Condition, an informal statement of which is repeated in (17).

(17) *The Prominence Condition*

> Markedness constraints specific to strong positions are included in CON only if the general markedness constraints from which they are built call for the presence of perceptually prominent properties.

The Prominence Condition thus states that the only legitimate **M/str** constraints are those that are positional versions of augmentation (prominence-enhancing[11]) constraints. This requirement correctly predicts the existence of the **M/str** constraints responsible for the empirically attested requirements on strong positions listed above, and the non-existence of empirically problematic **M/str** constraints such as the putative *MIDV/σ́.

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[11]The term *enhancement* as used here, in the context of *enhancement of the perceptual prominence of a strong position,* is not related to *featural enhancement* in the sense of Stevens & Keyser (1989). *Featural* (or *contrast*) *enhancement* refers to the tendency that languages have to assign values for non-contrastive features such that they enhance the perceptual difference between the opposing values for a feature that is contrastive. For example, if [±round] is non-contrastive for vowels in a language, then usually front vowels will be redundantly [-round] and back vowels will be redundantly [+round]. This patterning of the non-contrastive feature [±round] is said to "enhance" the contrast between front and back vowels, because it increases the difference in their F2 values that is the primary acoustic correlate of the front/back contrast. On the other hand, *enhancement of perceptual prominence* refers to an increase in the perceptual salience of a given entity (segment, syllable, morpheme), as measured by, e.g., magnitude of neural response to that entity as a stimulus.

The concept behind the Prominence Condition is this. The **M/str** constraints that comply with the Prominence Condition are exactly those constraints that take a strong position, which by definition is already prominent along some phonetic or psycholinguistic dimension, and require it to become even more prominent through association with some perceptually salient property. When **M/str** constraints are satisfied, "the strong get stronger."

This characteristic is consistent with a general pattern that many markedness constraints follow: a mandate for the co-occurrence of mutually reinforcing properties. For example, Stevens & Keyser (1989) argue that certain feature co-occurrence patterns are marked because they give rise to conflicting cues in the acoustic signal — e.g., prototypical obstruents have no low-frequency energy, because sonorants do; voicing an obstruent adds low-frequency energy to the signal; so voiced obstruents are marked. Restating Stevens & Keyser's (1989) claim in OT terms, there is a markedness constraint requiring obstruents to be voiceless, because voicelessness makes obstruents more like prototypical obstruents. The co-occurrence of mutually reinforcing properties can also be seen as the basis of the operation of "harmonic alignment" (Prince & Smolensky 1993:67, 136), which forms universal constraint subhierarchies like *ONSET/X and *PEAK/X that favor an association between the prominent ends of two scales (e.g., syllable peaks and high-sonority segments) and the non-prominent ends of those scales (e.g., syllable onsets and low-sonority segments).

Conversely, **M/str** constraints that are not augmentation constraints, such as the putative *MIDV/σ́, would if anything make strong positions *less* prominent by stripping away potential phonological contrasts without adding to the perceptual salience of the position. With the Prominence Condition in place, such constraints are correctly predicted not to be included in CON.

In the Schema/Filter model of CON, the Prominence Condition can be formally implemented as a member of the set of constraint filters. Thus, any markedness (or faithfulness) constraint can be relativized to any strong position by means of the **C**/*str* constraint schema. However, any **M/str** constraint thus constructed must be tested by the Prominence Condition, now explicitly modeled as a substantively based constraint filter that is designated to apply to **M/str** constraints (18).

(18) *The Prominence Condition* (as a constraint filter)

If a constraint is of the form **M/str**, then it must meet the following condition:

> **M** must be an augmentation constraint, i.e., a constraint that calls for the presence of a perceptually prominent property.[12]

A formally possible **M/str** constraint that does not meet the requirements imposed by the Prominence Condition, such as *MIDV/σ́, is not passed by this filter and so is not included in the set of universal constraints from which language-particular OT grammars are formed.

As is the case with all constraint filters in the Schema/Filter model (see §2.2.1.2), the Prominence Condition makes use of substantive information from outside the formal phonological system when it evaluates constraints for compliance. In this case, the crucial information has to do with perceptual prominence: are candidates that satisfy a given markedness constraint more perceptually prominent than candidates that violate the constraint? If so, the constraint passes the Prominence Condition.

Perceptual prominence itself can perhaps be measured in terms of neural response, since auditory-nerve firing rate is known to be higher when signal intensity is greater (Delgutte 1997, Geisler 1998). That is, it may be appropriate to categorize one stimulus as more perceptually prominent than another if the first stimulus elicits a neural response of greater magnitude than that elicited by the second. However, the task of the Prominence Condition — to decide whether a particular **M/str** constraint acts to *enhance* perceptual prominence — is somewhat more complex than comparing the neural responses produced by a given pair of stimuli. It is also necessary to ensure that the stimuli to be compared are the appropriate ones.

In the case of the Inductive Grounding Principle, Hayes (1999a) proposes that a feature-co-occurrence or feature-context constraint (such as *[-son, +voi]) is inductively grounded if the boundary between feature combinations that satisfy the constraint and those that violate it correctly partitions speakers' general-knowledge "map of phonetic difficulty" into regions of easier and more difficult articulations (§2.2.1.2). But in the case of the Prominence Condition, which must determine whether a particular markedness constraint is one that calls for the presence of perceptually prominent characteristics, it is not enough just to see whether all (or most) candidates that satisfy the constraint are more perceptually prominent than all (or most) candidates that violate it. For example, the markedness constraint *[labial] is violated by [pe] and satisfied by [keːta]. The latter candidate, with a long vowel and an additional syllable, will certainly give rise to a larger neural response than the former, simply because it has a longer

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[12]By hypothesis, the Prominence Condition tests the general version of the constraint, rather than the relativized version, for its ability to enhance perceptual prominence. The status of a constraint as an augmentation constraint is therefore independent of any strong position it might be relativized to.

overall duration. However, intuitively, this fact should not be used to show that *[labial] is an augmentation constraint, because factors other than the difference between [p] and [k] are what really make the second candidate more perceptually prominent than the first.

Therefore, to test whether a particular markedness constraint **M** qualifies as an augmentation constraint (and so may have an **M/str** counterpart), it is necessary to compare a pair of output candidates that are as close to identical as possible in all respects other than whatever property determines the satisfaction or violation of **M**. That is, the candidates that are compared must be a kind of "minimal pair". The compliance-testing procedure for the Prominence Condition will thus be something like the following.

For a given markedness constraint **M**, choose an arbitrary input and consider a set of two minimally different output candidates such that one satisfies **M** and one violates **M**. Minimally different output candidates are those whose input-output faithfulness violations, computed with respect to the arbitrary input, differ only in that one candidate has one fewer violation of one faithfulness constraint than the other candidate has. (In cases where the violation of one faithfulness constraint entails the violation of others, minimally different candidates are those that differ by the smallest number of faithfulness violations possible). Because the two candidates differ only in one aspect of their faithfulness to the arbitrary input, they are nearly identical. This requirement forces their one point of difference to be relevant to the demands of the **M** being tested, since the two output candidates must differ in their satisfaction of **M**, but can only differ in one property. Under these conditions, if the **M**-satisfying candidate is judged to be more prominent than the **M**-violating candidate when the two are fed to the perceptual system, then **M** is an augmentation constraint, and any **M/str** constraint constructed from **M** passes the Prominence Condition.

For example, consider the **M/str** constraint HEAVYσ/σ́. The **M** constraint from which it is built is HEAVYσ (§2.3.2.1), so an arbitrary input and two minimally different output candidates as specified above are considered with respect to this constraint. The faithfulness constraint by which these candidates differ is MAX-μ, which penalizes the deletion of an input mora (McCarthy & Prince 1995; Itô, Kitagawa, & Mester 1996; McCarthy 2000).

(19) Testing HEAVYσ/*str* for compliance with the Prominence Condition

/taː/	HEAVYσ	...	MAX-μ
a. taː			
b. ta	*		*

Since candidate (19a), which satisfies HEAVYσ, is more perceptually prominent (see §2.3.2.1) than candidate (19b), which violates the constraint, this means that HEAVYσ qualifies as an augmentation constraint, so the **M/str** constraint HEAVYσ/σ́ is well-formed according to the

Prominence Condition. Note that the same result would emerge if the arbitrary input had been /ta/, with a short vowel, since (19a) would still be more perceptually prominent than (19b).[13] It is not relevant which of the two output candidates is *more* faithful to the arbitrary input; they must just be *minimally different* in their faithfulness violations.

This proposal for how the Prominence Condition uses information from the perceptual system to identify augmentation (prominence-enhancing) constraints is somewhat preliminary and may need to be further refined as additional cases are considered. For example, as noted above, the putative stressed-syllable markedness constraint *MIDV/σ́ is not a member of CON, and in fact including this constraint in CON would allow for a pattern that does not occur: the avoidance of specifically mid vowels in stressed syllables. The absence of *MIDV/σ́ from CON is correctly predicted by the general principle behind the Prominence Condition, since forcing vowels to be peripheral rather than mid is not fundamentally a means of enhancing perceptual prominence (as discussed in §2.3.2.3, some non-mid vowels, namely high vowels, are *less* perceptually salient than mid vowels are). However, care must be taken that the specific implementation given to the Prominence Condition as part of the Schema/Filter model does not allow *MIDV/*str* to slip into CON. The problem is that mid vowels are in fact less perceptually prominent than *some* peripheral vowels, i.e., low vowels (§2.3.2.3). It is therefore possible to imagine a scenario where *MIDV is tested for compliance with the Prominence Condition and the arbitrary input happens to contain a low vowel.

(20) Testing *MIDV for compliance with the Prominence Condition

/tæ/	*MIDV	...	IDENT[Vht]
a. tæ			
b. te	*		*

In this case, the candidate that satisfies *MIDV, (20a), does happen to be more perceptually prominent than the candidate that violates the constraint, (20b). Yet this is only a coincidence. If the arbitrary input had been /ti/, the reverse result would have been true: the candidate satisfying *MIDV ([ti]) would have been *less* perceptually prominent than its competitor ([te]). Therefore, it may be necessary for the Prominence Condition to test multiple arbitrary inputs when it examines a given markedness constraint in order for it to determine whether the property mandated by that constraint is truly one that enhances perceptual prominence — as opposed to one, like *MIDV, whose satisfaction may under some circumstances coincidentally increase perceptual salience.

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[13]In that case, the faithfulness constraint on whose satisfaction the two candidates differ would be DEP-μ (penalizing the insertion of a mora) rather than MAX-μ, but there would still be only a single difference in faithfulness violations between the two candidates.

The following subsection (§2.3.2) examines the predictions made by implementing the Prominence Condition as a member of the set of substantively based constraint filters, and shows that these predictions match empirical patterns; each markedness constraint known to have an **M/str** counterpart is shown to be a constraint that does indeed call for the presence of a perceptually prominent property.

2.3.2 Augmentation constraints

The **M/str** constraints exemplified in chapters 3 and 4 are positional versions of the following set of constraints.

(21) Markedness constraints with **M/str** counterparts

HEAVYσ	(§2.3.2.1)
*PEAK/X	(§2.3.2.2)
ONSET	(§2.3.2.3.2)
*ONSET/X	(§2.3.2.3.3)
HAVECPLACE	(§2.3.2.4)
HTONE	(§2.3.2.5)
HAVESTRESS	(§2.3.2.6)

These individual constraints each have precedents in the OT literature, but here they are viewed as a group with a common characteristic. As predicted by the Prominence Condition, the markedness constraints with attested **M/str** counterparts are all constraints that act to enhance perceptual prominence.

This section discusses the relationship that each of the constraints given in (21) has with perceptual prominence. In addition, a formulation is developed for each constraint that explicitly identifies its focus. As discussed in §2.2.2, the constraint focus is important because it determines the strong positions to which a constraint can be meaningfully relativized. (See §2.3.3 below for discussion of which positional versions are predicted for each of these constraints.)

2.3.2.1 HEAVYσ

One of the most familiar examples of a phonological requirement that holds specifically of a strong position is that seen in the close relationship between stressed syllables and syllable weight: in some languages, stress is attracted to heavy syllables, while in other languages, stressed syllables themselves undergo lengthening. In §3.2.1, these two effects are shown to be responses to the same constraint, HEAVYσ/σ́, which penalizes monomoraic stressed syllables.[14]

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[14]See the end of this subsection (§2.3.2.1) for discussion of the relationship between HEAVYσ/σ́ and similar constraints that have been proposed in the literature, STRESS-TO-WEIGHT

(22) HEAVYσ/σ́ For all syllables *x*, if *x* is a σ́, then *x* dominates >1 mora

Some languages choose to satisfy this constraint by altering the stressed syllable (as by lengthening its vowel, or geminating or resyllabifying a following consonant), whereas other languages that satisfy this constraint do so by adjusting the location of the stress so that it falls on a syllable that is intrinsically heavy.

By the Prominence Condition, any markedness constraint that has an **M/str** counterpart must be an augmentation constraint, a constraint calling for some property that is perceptually prominent. Heavy syllable weight has long been recognized as a prominent characteristic, partly based on the very relationship between stress and syllable weight just described. In §2.3.1 above, prominence is defined in terms of relative perceptual response; on this basis as well, heavy syllables qualify as perceptually prominent. A bimoraic syllable is longer than a monomoraic one, since it contains either a longer peak (if CVː) or more segments (if CV_1V_2 or CVC) than a monomoraic (CV) syllable. Thus, a bimoraic syllable would give rise to a larger perceptual response than a monomoraic syllable, all else being equal.

There is a question that arises when the constraint HEAVYσ/σ́ is examined in the larger context of a theory of positional augmentation constraints: does it have a non-positional counterpart, HEAVYσ? Thus far, **M/str** constraints — markedness constraints that make specific reference to strong positions — have been viewed as the relativized counterparts of general markedness constraints. That is, all constraints of the form **M/str** have been assumed to be formed by the **C**/*str* schema, which combines a general **M** constraint and a member of the set of strong positions (§2.2.1.1; §2.2.2). Many **M/str** constraints, such as ONSET/σ_1 or [*PEAK/X]/σ́, clearly are positional counterparts of well-attested general **M** constraints, in this case ONSET and *PEAK/X. However, evidence for the existence of a general constraint HEAVYσ is not as strong.

General HEAVYσ would have the following formulation, without the *if-then* clause that relativizes HEAVYσ/σ́ (22) to stressed syllables (see §2.2.2 above on the formal relationship between positional and general constraints).

(23) HEAVYσ For all syllables *x*, *x* dominates >1 mora

A constraint calling for all syllables to be heavy does have some precedent in the phonological literature. For example, all Dutch non-schwa syllables have been argued to be bimoraic (van der Hulst 1984, 1985; Kager 1990; but cf. Gussenhoven 2000). It has also been proposed that in various Chinese languages, all tone-bearing syllables are bimoraic (Woo 1969; Yip 1980). An OT constraint equivalent to HEAVYσ, called QUANTITY, is introduced by Hammond (1997) for his analysis of English vowels, based on Kager's (1990) account of Dutch.

(Prince 1990) and PK-PROM (Prince & Smolensky 1993; Kenstowicz 1994).

Of course, there are also many languages with only monomoraic syllables (i.e., typical "quantity-insensitive" languages). This fact might seem to indicate that there is a constraint *against* bimoraic syllables. However, constraints against bimoraic vowels, against diphthongs, and against moraic consonants (including coda consonants) are all independently motivated (Rosenthall 1994; Broselow, Chen, & Huffman 1997). If all these constraints were ranked high in a particular language, their combined effects would allow only monomoraic syllables, without the need for a constraint that specifically bans bimoraic syllables.[15]

Whatever the ultimate status of a general HEAVYσ constraint, nothing in the theory of **M/str** constraints developed here crucially depends on its existence. If this constraint does not in fact exist, there are two possible explanations for its absence that are consistent with this framework. First, it is possible that HEAVYσ as well as HEAVYσ/σ́ is among the set of formally possible constraints that are examined by the constraint filters, but there is some constraint filter that prevents general HEAVYσ from being included in CON.

Second, it is conceivable, although less conceptually appealing, that some **M/str** constraints are themselves primitives of the model, rather than being constructed compositionally from general **M** constraints by the **C**/*str* schema. Crucially, the prediction would still be made that such constraints must pass the Prominence Condition, since this filter acts upon all constraints of the form **M/str**, whether they came from the **C**/*str* schema or were somehow independently constructed.

A final point to note in this subsection is that the stressed-syllable version of this constraint, HEAVYσ/σ́, has a close relationship to several constraints and principles that have previously been introduced in the phonological literature, particularly the Stress-to-Weight Principle (SWP) of Prince (1990), and the constraint PEAK-PROMINENCE (PK-PROM), introduced by Prince & Smolensky (1993).

The Stress-to-Weight Principle is so named in Prince (1990), although there are several earlier analyses of vowel lengthening and resyllabification under stress that invoke an analogous weight requirement for stressed syllables (e.g., Chierchia 1982; Borowsky, Itô, & Mester 1984). Prince states this principle as follows.

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[15]Even if there turns out to be indisputable evidence in favor of a constraint against bimoraic syllables — perhaps as a member of the *STRUCTURE constraint family (Zoll 1993; also Zoll, p.c., cited in Prince & Smolensky 1993:25) — this does not necessarily mean that HEAVYσ does not exist. There are different "dimensions" of markedness, and a given phonological configuration is often seen to violate one markedness constraint while being demanded by another. FTBIN, which requires feet to be binary (Prince 1980; McCarthy & Prince 1986, 1993ab), is a classic example of a prosodic constraint that is directly antagonistic to *STRUCTURE constraints, in the same way that HEAVYσ would be.

(24) Stress-to-Weight Principle (Prince 1990:358)

If stressed, then heavy

The SWP requires any stressed syllable to be a heavy, so it is clearly identical to HEAVYσ/σ́. (The name HEAVYσ/σ́ is nevertheless used here in the interest of maintaining a consistent, transparent "**M/str**" naming system for positional augmentation constraints.)

The status of the SWP in Prince (1990) is actually somewhat ambiguous. Prince first states it as a logically possible principle that he will nonetheless "specifically deny" has the status of an actual principle (Prince 1990:358). Then, in a footnote, he retracts a bit from this initial claim: "A more even-tempered position would hold that Stress-to-Weight is a principle, but one with a different [i.e., subordinate —JLS] position than Weight-to-Stress in the ranking of rhythmic priorities" (Prince 1990:388, note 6).

Prince's (1990) view of the SWP should be understood in the context of a major goal of that paper, which is to use the Weight-to-Stress Principle (WSP; 'if heavy, then stressed') and considerations of foot form to account for cross-linguistic patterns of iambic lengthening and trochaic shortening. Prince (1990:376) himself observes that the system he has developed is unable to account for the trochaic *lengthening* that occurs under stress in English and similar languages (cf. West Germanic, addressed in §3.2.1.1). This is precisely the kind of case that the SWP~HEAVYσ/σ́ can account for.

Indeed, once the WSP and the SWP (the latter commonly under the guise of PK-PROM; see below) are incorporated into OT where all constraints are violable, it is generally acknowledged that both types of 'principle' or constraint are necessary, in addition to constraints regulating foot form (e.g., Prince & Smolensky 1993; Walker 1996).[16]

The other constraint that is closely related to HEAVYσ/σ́ is PK-PROM, a constraint often invoked to account for unbounded stress systems, in which syllables having certain properties preferentially bear stress. The original formulation of this constraint is given as follows (Prince & Smolensky 1993:39).

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[16]Specifically, the WSP is crucially needed for languages that have obligatory stress (primary or secondary) on all heavy syllables, a pattern that cannot be accounted for by the SWP, which would be satisfied if just one of several heavy syllables were to bear stress. However, the SWP is also necessary. It is needed to account for stressed-syllable lengthening effects (particularly in trochaic systems, where no appeal to "uneven iambs" can account for weight gain in stressed syllables); since the WSP would be perfectly satisfied by a light stressed syllable if there were no heavy syllables in a form, it cannot force a stressed syllable to become heavy. See, e.g., Holt (1997) and Gussenhoven (2000), who implement the SWP as an OT constraint to account for stressed-syllable lengthening effects in the Iberian languages and Dutch respectively. Additional discussion of stressed-syllable lengthening is given in §3.2.1.1.

(25) Peak-Prominence (PK-PROM) Peak(x) ≻ Peak(y) if $|x| > |y|$

This formulation says that "the element *x* is a better peak than *y* if the intrinsic prominence of *x* is greater than that of *y*," where *x* and *y* are syllables and "peak" here refers to word peak, i.e., main stress (Prince & Smolensky 1993:38-9). There is reason to believe, however, that (25) is intended to be an encapsulation of several simpler constraints rather than a formal constraint definition. PK-PROM as given in (25) has the same structure as another constraint provisionally proposed by Prince & Smolensky (1993:16), HNUC (26), and HNUC is eventually replaced by the *PEAK/X subhierarchy in Prince & Smolensky's system for reasons to be described below.

(26) Nuclear Harmony Constraint (HNUC) If $|x| > |y|$ then Nuc/x ≻ Nuc/y

This time, *x* and *y* are segments, and HNUC says that a segment of higher intrinsic prominence (greater sonority) is a better syllable nucleus than one of lower intrinsic prominence.

In addition to being constraints that evaluate relative prominence, PK-PROM and HNUC are also both what Prince & Smolensky (1993) call "non-binary constraints," because the marks that they assign to candidates involve not a choice between satisfaction and violation (✓ versus *), but symbols that represent the levels of prominence of the objects that they evaluate (|a| versus |i| versus |n|, for example). However, Prince and Smolensky (1993:134) later go on to decompose HNUC into the *PEAK/X subhierarchy, consisting of the universally ranked *binary* constraints *PEAK/[t] >> ... >> *PEAK/[n] >> ... >> *PEAK/[a] (see also §2.3.2.2). They note:

> As might be suspected, it will turn out that the work done by a single non-binary constraint like HNUC can also be done by a *set* (indeed a sub-hierarchy) of binary constraints. (Prince & Smolensky 1993:81)

Thus, although Prince & Smolensky (1993) themselves never explicitly reformulate PK-PROM by means of binary constraints, it seems clear that they intend PK-PROM as an expository convenience, an encapsulation of various binary constraints relating stress and syllable prominence, rather than as an actual single constraint in the system. Subsequent researchers who invoke PK-PROM (e.g., Walker 1996) generally do so in the spirit in which it was intended — as an encapsulation.

The relationship of HEAVYσ/σ́ to PK-PROM becomes apparent once the individual binary constraints that will be needed to replace this encapsulated constraint are considered. As is explicitly noted in most analyses that make use of encapsulated PK-PROM (e.g., Prince & Smolensky 1993; Walker 1996), the particular property that qualifies as 'prominence' for stress placement varies from language to language, including such characteristics as mora count, vowel sonority, tone, and onset profile (see also Hayes 1995:Ch 7). Thus, it is necessary to recognize distinct constraints or constraint subhierarchies, each of which requires stressed syllables to have one of these distinct dimensions of prominence.[17] The subcomponent of PK-PROM that relates stressed syllables to syllable weight is a constraint that says, "Stressed syllables are heavy;" that is, it is none other than HEAVYσ/σ́. Thus, HEAVYσ/σ́ is "part of" PK-PROM. (Other constraints that enforce stress-prominence interactions, and so are needed to help decompose PK-PROM, include HTONE/σ́, [*PEAK/X]/σ́, ONSET/σ́, and [*ONSET/X]/σ́. These constraints, along with HEAVYσ/σ́, are exemplified and further discussed in §3.2. The general **M** constraints from which these **M**/σ́ constraints are built are presented later in the current section, §2.3.2.)

In summary, HEAVYσ/σ́ is equivalent to the Stress-to-Weight principle (Prince 1990), and it is one of the individual constraints that is encapsulated by PK-PROM (Prince & Smolensky 1993). The SWP has typically been invoked in cases where stressed syllables are required to become heavy, whereas PK-PROM has generally been used to explain the attraction of stress to syllables that are already heavy. Recognizing that these two are in fact the same constraint means that two distinct types of phonological behavior — stressed-syllable lengthening and the attraction of stress to heavy syllables — can be directly related. (See §3.2 for further discussion, and for extensions of this approach to the relationship between stress and other dimensions of prominence beyond syllable weight.)

2.3.2.2 *PEAK/X

Another phonological requirement that is observed in some languages to hold of strong positions (in particular, of stressed syllables and long vowels) is the requirement that syllable peaks in those positions be high in sonority.

The general (non-positional) markedness constraints responsible for demanding high-sonority syllable peaks are the members of the *PEAK/X subhierarchy (Prince & Smolensky 1993). This constraint subhierarchy is based on the segmental sonority scale; the members of the subhierarchy can each be given the explicit formulation in (27).

(27) *PEAK/X For every segment *a* that is the head of some syllable *x*, $|a| > X$
where $|y|$ is the sonority of segment *y*
X is a particular step on the segmental sonority scale

[17] Previous analyses that expand PK-PROM in order to account more directly for the kinds of prominence-sensitive stress systems that are attested cross-linguistically include Kenstowicz (1994), which focuses specifically on peak prominence related to vowel sonority (see the discussion of *PEAK/X in §2.3.2.2); de Lacy (1997), which replaces PK-PROM with a number of constraints sensitive to prosodic branchingness (explicitly rejecting mora count as relevant), and de Lacy (1999), which explores the relationship between stress peaks and troughs on the one hand and high and low tone on the other (see also the discussion of HTONE in §2.3.2.5).

Prince and Smolensky (1993:136) propose that the members of the *PEAK/X subhierarchy are in a universally fixed ranking that is determined by *harmonic alignment*. That is, syllable peak (nucleus) and syllable margin (onset or coda) form a prominence scale Peak > Margin ('Peak is more prominent than Margin'), and the steps of the segmental sonority hierarchy also form a prominence scale *a* > ... *n* > ... > *t*. Harmonic alignment is an operation that combines two such prominence scales into constraint subhierarchies with universally fixed rankings. Here, since Peak is more prominent than Margin, Peak preferentially co-occurs with the prominent end of the segmental sonority scale and disprefers the non-prominent end, giving rise to the *PEAK/X subhierarchy, *PEAK/T >> ... >> *PEAK/NAS >> ... >> *PEAK/LOWV.[18]

Because the members of the *PEAK/X subhierarchy demand that a syllable peak be high in sonority, these constraints qualify as augmentation constraints. The precise definition of sonority is somewhat controversial (see Parker 2002 for a review of the relevant literature), but many proposals involve a property related to acoustic intensity, amplitude, clear formant structures, and perceptual salience (representative works include Sievers 1881, Bloomfield 1933, Bloch & Trager 1942, Selkirk 1984, Keating 1983, Clements 1990, Pierrehumbert & Talkin 1992, Lavoie 2000, Parker 2002).

The sonority scale adopted here, from which the identity of the individual members of the *PEAK/X subhierarchy is determined, is given in (28) (see Sievers 1881, Jespersen 1904, Steriade 1982, Selkirk 1984, and the "consonantal strength scale" of Vennemann 1988).[19]

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[18]Prince & Smolensky (1993:134) also propose a *MARGIN/X subhierarchy from harmonic alignment, *MARGIN/LOWV >> ... >> *MARGIN/NAS >> ... >> *MARGIN/T, in which less prominent Margin preferentially co-occurs with the less prominent end of the segmental sonority scale. See §2.3.2.3.2 for discussion of *ONSET/X, which is based on *MARGIN/X.

[19]Although there is much about the sonority scale that is widely accepted, there are a few points of contention in the literature, stemming mostly from cases where one language or one phonological phenomenon appears to treat segment class *A* as higher in sonority than segment class *B*, while a different language or a different phenomenon seems to treat *B* as higher in sonority than *A*. This kind of problem — where near-universal tendencies are overridden in particular languages or in particular circumstances — is often amenable to an OT solution in terms of constraint conflict. It is therefore likely that these apparent "sonority reversals" can be accounted for by ranking some other constraint above those constraints concerned with sonority; constraint domination thus leads to "exceptional" behavior from the point of view of sonority.

One such controversy is the question of whether the glottal segments [h, ʔ] are low in sonority, like obstruents, or high in sonority, like glides. In the discussion of HAVECPLACE in §2.3.2.4, it is argued that these segments are classified as obstruents for the purposes of sonority, and that occasions when they behave differently from obstruents are caused by their lack of a supralaryngeal place specification rather than by anything to do with sonority. Thus, in a system in which constraints are violable, we are not forced *a priori* to abandon a proposed step or division of the segmental sonority scale simply because it is not universally observed.

(28) Sonority scale

high sonority	low vowels
	mid vowels
	high vowels/glides
	rhotics
	laterals
	nasals
	voiced obstruents
low sonority	voiceless obstruents

This version of the sonority scale is partitioned finely enough to account for the onset sonority- and peak sonority-sensitive phenomena encountered in the case studies in chapters 3 and 4. In addition to sonority divisions among the major classes of segments, vocoids > liquids > nasals > obstruents (Clements 1990; Zec 1988), a few additional divisions are also recognized. Namely, the class of liquids is divided into rhotics > laterals; the class of obstruents is divided into voiced > voiceless, and the class of vocoids is divided into low vowels > mid vowels > high vowels/glides.

Evidence for these finer sonority distinctions comes from phonological patterns in a number of languages and from phonetic characteristics of the sounds in question. First, consider the rhotic > lateral division. Rhotics often pattern with glides rather than with laterals in sonority-sensitive phenomena, showing that rhotics are higher in sonority than laterals. In Icelandic, for example, the rhotic and the glides [j, w], but not the lateral, can be syllabified together with a preceding obstruent into an onset cluster word-medially (Einarsson 1949, cited in Devine & Stephens 1994). Also, rhotics are more compatible with syllable-peak status than laterals in several languages. Zec (1995) provides two examples: in Gonja, the single liquid phoneme is realized as [r^{w}] when syllabic and as [l] when not syllabic, and in Serbo-Croatian, [r] can be syllabic but [l] cannot. (See also the discussion of English in §3.2.1.3.) From a perceptual standpoint, laterals are like nasals in that both have abrupt spectral discontinuities in the transition to an adjacent vowel, but rhotics are like glides in lacking such discontinuities (J. Kingston, p.c.; see Espy-Wilson 1992 for the specific case of [l] versus [r j w] in American English).[20] If rhotics share acoustic characteristics with glides, and laterals with nasals, then this supports the claim that rhotics are higher in sonority than laterals.

There is also a phonetic basis for the proposed sonority distinction between voiced and voiceless obstruents. Stevens & Keyser (1989) argue that since the canonical auditory characteristic of a sonorant is the presence of low-frequency energy in the signal, voiced obstruents, which have low-frequency energy contributed by phonation, are auditorily more like

[20]Kingston (p.c.) notes that despite the articulatory diversity within the class of rhotics, most or all rhotics, from retroflex approximants to coronal and uvular trills, seem to share this property.

sonorants than voiceless obstruents are. Phonologically, voiced obstruents pattern as though they are higher in sonority than voiceless obstruents (see the discussion of Pirahã in §3.2.2.4). Also, the voicing of obstruents is a common form of synchronic and diachronic lenition, and non-place-related lenition is often defined as a change that causes an increase in the sonority of a segment (Lavoie 2000 and references therein).[21]

Finally, many of the segmental sonority scales that have been proposed, including those of Jespersen (1904), Selkirk (1984), and Vennemann (1988), recognize distinctions among the vowels according to height. Phonetically, the lower a vowel, the greater the degree of jaw opening, which results in more airflow and higher acoustic intensity at low frequencies (Keating 1983). Phonological motivation for recognizing this distinction comes from languages with sonority-sensitive phenomena that distinguish among vowel heights. For example, Kobon (Kenstowicz 1994, who attributes the example to "Davies 1981") assigns stress to low vowels when possible, to mid vowels when no low vowels are available, and to high vowels when no low or mid vowels are available.[22]

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[21]Languages apparently differ in which divisions among the class of obstruents are most phonologically relevant. In some languages, the stop/fricative distinction is primary and the voiceless/voiced distinction is secondary; that is, all fricatives are higher in sonority than all stops, with a voiced > voiceless division inside each group (as in Imdlawn Tashlhiyt Berber; Dell & Elmedlaoui 1985, 1988). But in Pirahã (§4.2.3.2), the voiceless/voiced distinction is primary — all voiced obstruents are higher in sonority than all voiceless obstruents, including the voiceless fricatives.

Zec (1988:94) tries to avoid the problem of conflicting subdivisions within the class of obstruents by proposing that the feature [voice] cannot be used to define a sonority class. Zec makes this choice because she has already proposed that [continuant] *can* be used to make sonority distinctions, and she wants to make the above kind of cross-cutting classification impossible. However, the two primary ways of dividing the class of obstruents are both attested, in IT Berber and Pirahã respectively. Moreover, given that there is an acoustic difference between voiced and voiceless obstruents of the sort that is relevant for sonority — greater low-frequency energy for voiced than for voiceless obstruents — it seems well motivated to divide the class of obstruents according to [voice]. Perhaps the phonologically different behavior of stops and fricatives, in languages that do distinguish the two, is the result of some constraint related to a property other than sonority, which can be ranked differently in different languages (similar to the approach taken in §2.3.2.4 below for glottal consonants). For now, since the status of stops versus continuants is not crucial for any of the positional augmentation examples considered in chapters 3 and 4, this question is pursued no further. See also Morén (1999) for arguments that obstruent voicing is relevant for sonority.

[22]It has sometimes been proposed that central or reduced vowels, such as schwa, also differ from other vowels in terms of sonority. For example, reduced vowels are placed on the sonority scale below high vowels by Kenstowicz (1994), because many languages prefer high vowels over schwa for stress assignment — including Kobon, mentioned above, which prefers

In conclusion, based on the segmental sonority scale in (28), the *PEAK/X subhierarchy is composed of the following individual constraints (29), each of which has the formulation in (30). (*T* and *D* in (29) are abbreviations for "voiceless obstruents" and "voiced obstruents" respectively.)

(29) The *PEAK/X subhierarchy

*PEAK/T >> *PEAK/D >> *PEAK/NAS >> *PEAK/LAT >> *PEAK/RHO >>

*PEAK/HIGHV >> *PEAK/MIDV >> *PEAK/LOWV

(30) *PEAK/X For every segment *a* that is the head of some syllable *x*, |*a*| > X
where |*y*| is the sonority of segment *y*
X is a particular step on the segmental sonority scale

Further confirmation of the sonority divisions within major classes that are included in (28) and (29) is provided by several of the languages discussed in chapters 3 and 4. For rhotic > lateral, see English syllabic sonorants (§3.2.1.3) and word-initial liquids in Sestu Campidanian Sardinian and Mbabaram (§4.2.1.2). For voiced obstruents > voiceless obstruents, see Pirahã (§3.2.2.4). For sonority divisions among vowels, see Zabiče Slovene and Mokshan Mordwin (§3.2.1.3) and Yawelmani (§3.3).

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high vowels to [ɨ, ə], and Mokshan Mordwin (§4.2.5.2), which prefers mid vowels to schwa as well as to high vowels. However, admitting the constraint *PEAK/REDV, against reduced vowels, into the *PEAK/X subhierarchy has an undesired consequence. Since the *PEAK/X subhierarchy and the *ONSET/X subhierarchy (see §2.3.2.3.2 below) are both built from the sonority hierarchy, then these two subhierarchies must contain the same steps. But *PEAK/HIGHV >> *PEAK/REDV implies *ONSET/REDV >> *ONSET/GLI(=HIGHV) — namely, that reduced vowels make better onsets than glides do. This certainly does not seem to be the case. I therefore make a provisional proposal, analogous to that for the glottal consonants [h, ʔ] (see §2.3.2.4). Namely, reduced vowels differ from other vowels not in terms of sonority, but in terms of a separate dimension that is not related to the segmental sonority scale, and it is a constraint disfavoring that particular characteristic of reduced vowels that causes stress to avoid them.

If reduced vowels differ from full vowels in lacking vowel-place features, then the constraint in question might be HAVEVPLACE. However, Hammond (1997) argues that schwa in English is not placeless, but rather fails to sponsor a mora. Furthermore, there are languages, like Kobon, where there is a phonological contrast between different reduced vowels (both of which are avoided for stress). So lack of place features may not be what sets reduced vowels apart.

2.3.2.3 ONSET and *ONSET/X

Two further phonological requirements that are empirically observed to apply specifically to strong positions (in this case, stressed syllables and initial syllables) are the requirement that syllables in strong positions have onsets and the requirement that syllable onsets in strong positions be low in sonority.

For many of the strong-position markedness requirements discussed here, the Prominence Condition is clearly met; it is widely accepted that characteristics such as syllable weight (§2.3.2.1), high syllable-peak sonority (§2.3.2.2), and high tone (see §2.3.2.5 below) are perceptually prominent. However, the relationship between the Prominence Condition and constraints calling for onsets (ONSET) or low-sonority onsets (the *ONSET/X subhierarchy) is less obvious — CV syllables are less marked than onsetless syllables, and low-sonority onsets are less marked than high-sonority onsets, but these facts alone do not entail that syllables with onsets or low-sonority onsets are more perceptually prominent than other syllables. (As discussed in §2.3.2.2 above, lower sonority means lower prominence, so onset consonants themselves are actually *less* perceptually prominent when *ONSET/X constraints are satisfied.)

This section presents evidence from neural response patterns that the presence of an onset, and specifically a low-sonority onset, does in fact enhance the perceptual response to a syllable (§2.3.2.3.1). Because this is the case, the Prominence Condition correctly predicts that there should be **M/str** counterparts of ONSET and the *ONSET/X subhierarchy. Explicit formulations for these constraints are given in §2.3.2.3.2 and §2.3.2.3.3 respectively.

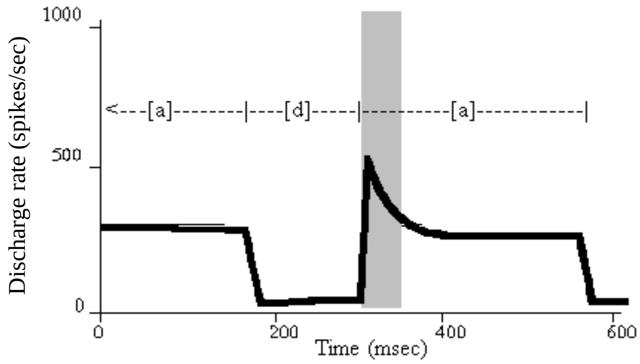
2.3.2.3.1 On the perceptual prominence of syllables with (low-sonority) onsets

Given a constant auditory stimulus such as a tone or a vowel-like sound, auditory-nerve fibers do not discharge at a constant rate. There is an initial higher response rate when the stimulus begins, followed by a decay in response rate that is known as *adaptation*. Adaptation has a physiological origin, because it is apparently caused by depletion of the neurotransmitter that stimulates the auditory-nerve fibers (R. Smith 1979). However, it also plays a role in speech perception:

> [A]daptation enhances spectral contrast between successive speech segments. ... [A] fiber adapted by stimulus components close to its CF [characteristic frequency] is less responsive to subsequent stimuli that share spectral components with the adapting sound. On the other hand, stimuli with novel spectral components stimulate 'fresh,' unadapted fibers, thereby producing an enhanced response. (Delgutte 1997:510)

Therefore, interspersing consonants (syllable onsets) between vowels gives the peripheral auditory system time to recover from adaptation, allowing enhanced response for each new vowel (syllable) in the string, as seen in (31).

(31) Neural response to synthesized [ada] (adapted from Delgutte 1997:531)



This figure is adapted from a post-stimulus time histogram for a high-spontaneous nerve fiber (CF=1800 Hz). The stimulus is a synthesized sequence [ada] (with equal intensity in both syllables). The shaded bar indicates the time interval occupied by the CV formant transitions, so its left edge marks the point of consonantal release.

At the time of release into the second [a], this nerve fiber shows some recovery from adaptation. The response rate there, at approximately 500 spikes per second, is larger than the response rate observed where adaptation has set in (i.e., the portion of the neural response to the first [a] that is shown,[23] and the response to the second [a] after about 350 ms).

Furthermore, if CV syllables are more prominent than V syllables because the onset consonant provides a contrast to the vowel (thereby allowing the peripheral auditory system time to recover from adaptation), it follows that syllables with low-sonority onsets are even more prominent than syllables with high-sonority onsets. A low-sonority onset such as a voiceless stop is maximally distinct from a vowel, and so would provide the best opportunity for recovery from adaptation.[24]

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[23]Responses to other stimuli by the same nerve fiber indicate that the initial response rate for the first [a], before adaptation, was probably between 500 and 700 sp/sec (Delgutte 1997:531).

[24]Discussion of the importance of spectral discontinuities in speech perception can also be found in, e.g., Stevens (1989) and Ohala (1992). Warner (1998) uses facts about adaptation, among other evidence, to argue for the importance of dynamic cues over static cues in speech perception. See also Silverman (1995) for another application of neural response patterns to phonological markedness; Silverman investigates a phenomenon separate from those considered here, namely, the relative markedness of different subsegmental orderings of features such as aspiration, but he gives detailed arguments for his phonological proposal based on neural

In summary, there is evidence from neural response patterns that syllables with onsets are more perceptually prominent than syllables without onsets, and further, that syllables with low-sonority onsets are more perceptually prominent than syllables with high-sonority onsets. As a result, ONSET and the *ONSET/X subhierarchy qualify as prominence-enhancing constraints, and **M/str** versions of these constraints are correctly predicted to pass the Prominence Condition.

Formulations of these constraints, and discussion of the motivation for the formulations, are given in the following two subsections.

2.3.2.3.2 ONSET

The constraint ONSET (Prince & Smolensky 1993), which requires syllables to have onsets, is the optimality-theoretic successor to ideas such as CV core syllable formation, onset maximization, and the Onset Principle (e.g., Clements & Keyser 1983; Itô 1986, 1989; Kahn 1976; Selkirk 1982; Steriade 1982). As described above, the substantive motivation for this constraint is the fact that recovery from neural adaptation is facilitated when vowels are separated by consonants.

The formulation of ONSET adopted here is given in (32).

(32) ONSET For all syllables x, $a \neq b$

where a is the leftmost segment dominated by x
b is the head of x

According to this formulation, ONSET requires that the head of a syllable not be the leftmost segment in the syllable. This version of the constraint is similar, but not identical, to the versions of ONSET proposed in Prince & Smolensky (1993) and McCarthy & Prince (1993a) (33).

(33) Previous formulations of ONSET

(a) Every syllable has an Onset [node] (Prince & Smolensky 1993:25)

(b) ALIGN-L (σ, C) (McCarthy & Prince 1993a:101)
('The left edge of every syllable is aligned with the left edge of some C')

The current formulation (32) differs from the previous formulations shown in (33) in two ways. First, (32) does not require the onset to appear in a particular syllabic position (cf. 33a). As a result, ONSET is satisfied by the presence of either a true structural onset (34a) or what is termed here a nuclear onglide (34b) (see §2.3.2.3.3 immediately below, and also §4.2.1.2.4, for discussion of the significance of this distinction).

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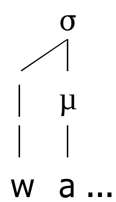
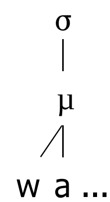
response patterns.

(34) (a) True onset



(b) Nuclear onglide



Second, ONSET as formulated in (32) does not make reference to the consonantal/vocalic status of segments (cf. (33b)). Evidence from Imdlawn Tashlhiyt Berber (Prince & Smolensky 1993, based on work by Dell & Elmedlaoui 1985, 1988, 1992) shows that ONSET is not sensitive to major-class features or other aspects of segmental sonority. ONSET is never violated in IT Berber (except in stem-initial position, where onset epenthesis would disrupt stem-to-PrWd alignment). Crucially, the drive to satisfy ONSET is able to force syllabifications like [.wL.] (where a capital letter indicates nuclear status) in [hA.wL.tN] 'make them (m.) plentiful'; clearly, to syllabify these two segments as [.Ul.] would provide a better nucleus, and the only explanation for why that syllabification is not chosen is that the actual syllabification [.wL.] satisfies ONSET (Prince & Smolensky 1993:17). And yet in this syllable, the leftmost segment, [w], is *not* lower in sonority than the nucleus, [l]. So what matters for satisfaction of ONSET is simply that there be a segment to the left of the head; the relative sonority of that segment with respect to the head is not important.

2.3.2.3.3 *ONSET/X

Another constraint, or rather set of constraints, that has its substantive basis in the perceptual advantage gained by interspersing low-sonority elements between vowels is the *ONSET/X subhierarchy, formulated as in (35).

(35) *ONSET/X For every segment *a* that is the leftmost pre-moraic segment[25] of some syllable *x*, |*a*| < X

where |*y*| is the sonority of segment *y*
X is a particular step on the segmental sonority scale

The *ONSET/X subhierarchy is a refinement of the *MARGIN/X subhierarchy of Prince & Smolensky (1993), which they state as follows.

(36) *MARGIN/X subhierarchy (Prince & Smolensky 1993:135)

*M/*a* >> *M/*i* >> ... >> *M/*t*

Just as with the *PEAK/X subhierarchy (see §2.3.2.2 above), Prince and Smolensky (1993:136) generate the *MARGIN/X subhierarchy through the harmonic alignment of two

[25] The term 'pre-moraic segment' designates a segment that precedes a tautosyllabic mora and is not itself dominated by a mora.

prominence scales: the syllable-position prominence scale Peak > Margin and the segmental sonority scale. Since a syllable margin is less intrinsically prominent than a syllable peak, Margin preferentially co-occurs with the non-prominent end of the segmental sonority scale.

Although the *ONSET/X subhierarchy implemented here is based on the *MARGIN/X hierarchy of Prince & Smolensky (1993), there are significant differences. As a comparison of the constraint names suggests, *ONSET/X constraints specifically enforce sonority requirements on syllable onsets, not on all 'margin' or non-peak positions, which would include codas and nuclear onglides as well. Furthermore, if a language allows onset clusters, only the leftmost segment of the onset is relevant for *ONSET/X constraints. These points are now addressed in turn.

The reason for excluding codas from the scope of this constraint subhierarchy is that, in general, the sonority restrictions that hold of onsets are not the same as those that hold of codas. Onsets are indeed preferentially low in sonority, as evidenced, for example, by Sanskrit reduplication (Steriade 1982), in which the lowest-sonority member of an onset cluster is copied into the reduplicant. However, many languages show a preference for *high*-sonority coda consonants (e.g., Hooper 1976; Zec 1988, 1995; Clements 1990). Prince & Smolensky (1993:162) themselves note that "the most Harmonic codas are generally regarded to be those which are *most* sonorous." Therefore, instead of grouping both onsets and codas together into a *MARGIN/X subhierarchy, which incorrectly predicts that low-sonority segments are preferred in codas as well as in onsets, it seems advisable to allow coda sonority to be regulated separately, by a different constraint or constraint subhierarchy.[26]

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[26]Perhaps *PEAK/X could be reinterpreted as *RIME/X, or *MORAIC-SEG/X (in the spirit of Zec 1988, 1995), so that it governs both nuclear and coda segments. The universal tendency for nuclei to be higher in sonority than codas could then be accounted for with constraints that call for the *head* mora of a syllable to be associated with the highest-sonority element. An approach that utilizes *MORAIC-SEG/X seems especially promising, since it could distinguish moraic codas, which are preferentially high in sonority, from nonmoraic syllable appendices, which are often voiceless (coronal) obstruents.

Prince & Smolensky (1993:162-3) sketch a few proposals that maintain the notion 'margin' as a cover term for onsets and codas. They suggest that either codas, being as it were in the margin of the rime, are subject to both Peak and Margin constraints, or there is a *RIME/X subhierarchy such that nuclei are subject to Peak and Rime constraints, codas to Margin and Rime constraints, and onsets to Margin constraints only.

Another way to formally model the greater preference for low sonority in onsets than codas would be to view the *ONSET/X subhierarchy itself as a case of positional augmentation, namely, as *MARGIN/X relativized to the strong position onset — leaving codas subject only to general *MARGIN/X (de Lacy 2000). With this system, it would be possible to generate a language that requires onsets to be lower in sonority than codas. However, there are two reasons why this approach is not taken here. First, as the case studies in chapters 3 and 4 show, *ONSET/X itself can be relativized to the strong positions stressed syllable and initial syllable. If

The reason for excluding nuclear onglides (34b) — pre-peak glides that are dominated by a mora rather than being immediately dominated by the syllable node — from the scope of *ONSET/X is because empirically, *ONSET/GLI is only violated by glides that are true structural onsets. Syllable-initial glides do not incur violations of *ONSET/GLI if they are affiliated with a mora. See §4.2.1.2, especially §4.2.1.2.4, for discussion and exemplification.

Finally, the restriction of *ONSET/X constraints to the *leftmost* onset segment predicts that languages with onset clusters will tolerate high-sonority onset segments if they are not initial in the syllable. In fact, the Sestu dialect of Campidanian Sardinian (§4.2.1.2.1) does tolerate stop-rhotic onset clusters in initial syllables, as in [tro.nu] 'thunder', even though simple rhotic onsets are prohibited in this position.

The *ONSET/X subhierarchy is based on the segmental sonority scale; this means that just as for *PEAK/X, the identity of the individual constraints in this subhierarchy is determined by the identity of the steps of the sonority scale that is to be adopted. Given the sonority scale motivated in §2.3.2.2 above, shown in (28) and repeated here in (37), the members of the *ONSET/X subhierarchy are as in (38). (Again, *D* and *T* are abbreviations for "voiced obstruents" and "voiceless obstruents" respectively.)

(37) Sonority scale

high sonority	low vowels
	mid vowels
	high vowels (glides)
	rhotics
	laterals
	nasals
	voiced obstruents
low sonority	voiceless obstruents

---

*ONSET/X were already a positional version of general *MARGIN/X, we would be forced to recognize the existence of "doubly positional" constraints. Second, it is not simply that onsets have a stronger tendency toward low sonority than codas do; rather, as Zec (1988, 1995) shows, there is an independent preference for codas to be *high* in sonority. This insight cannot be captured if general *MARGIN/X is the only sonority-related constraint governing codas.

(38) The *ONSET/X subhierarchy

*ONSET/LOWV >> *ONSET/MIDV >> *ONSET/GLI[27] >> *ONSET/RHO >>

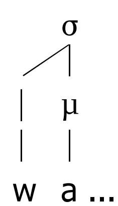
*ONSET/LAT >> *ONSET/NAS >> *ONSET/D >> *ONSET/T

Thus, ONSET and the members of the *ONSET/X subhierarchy are markedness constraints that are functionally grounded in a preference for demarcating vowels in the speech string with spectrally contrasting, low-sonority elements; furthermore, both ONSET and *ONSET/X qualify as augmentation constraints, because syllables with onsets, or with low-sonority onsets, are more perceptually prominent than other syllables. However, despite these basic similarities, there are important formal differences between ONSET and *ONSET/X. ONSET cannot simply be seen as another member of the *ONSET/X subhierarchy for two reasons: the ranking of ONSET is not fixed with respect to the members of the *ONSET/X subhierarchy, and moreover ONSET and *ONSET/X make reference to different aspects of syllable structure.

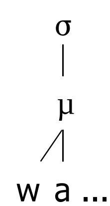
It might seem to be possible to recast ONSET as "*ONSET/Ø", a constraint against a "zero" onset. Such a constraint would have to dominate all the other constraints in the *ONSET/X subhierarchy, since a "zero" onset would be even less distinct from the syllable peak than a glide onset would be, and the members of the *ONSET/X subhierarchy are in a universally fixed ranking based on the sonority scale. However, there is evidence from Niuafo'ou that the stressed-syllable version of ONSET is in fact dominated by the stressed-syllable version of *ONSET/GLI: stressed syllables sometimes lack onsets altogether, but they never have glide onsets (§3.2.2.3). Thus, ONSET must be formally distinct from the *ONSET/X subhierarchy, since its ranking with respect to the members of *ONSET/X is not universally fixed.

Additionally, ONSET and *ONSET/X are sensitive to different aspects of subsyllabic structure. ONSET simply requires that the head segment not be leftmost in a syllable; as noted in §2.3.2.3.2 above, this means that ONSET is satisfied by a true consonantal onset, dominated by the syllable node (39a), as well as by a nuclear onglide, dominated by a mora (39b). On the other hand, *ONSET/X is sensitive only to segments syllabified as true onsets (39a).

(39) (a) True onset



(b) Nuclear onglide



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[27]The constraints *ONSET/GLI and *PEAK/HIGHV refer to the same class of segments, since the only difference between a high vowel and a glide is the segment's syllabic status. Thus, as an onset, such a segment will be a glide, and as a peak it will be a high vowel.

Evidence for this difference between ONSET and *ONSET/X comes from Guugu Yimidhirr and Pitta-Pitta (§4.2.1.2). In these languages, the initial-syllable versions of *ONSET/GLI, *ONSET/RHO, and *ONSET/LAT are all high-ranking (§4.2.1.2.2), but word-initial glides do nevertheless appear; this shows that the word-initial glides are syllabified as nuclear onglides and, crucially, that nuclear onglides do not violate *ONSET/GLI (see §4.2.1.2.4 for discussion). On the other hand, onsetless syllables are not tolerated in these languages, which shows that ONSET is undominated (§4.2.1.2.2). The fact that some words in these languages begin with nuclear onglides means that, along with true structural onsets, nuclear onglides must also be visible to, and satisfy, ONSET. Thus, as reflected in the constraint formulations given above, ONSET is sensitive to the presence of any pre-peak segment, regardless of its syllabic position, but *ONSET/X constraints are relevant only for true, non-moraic onsets.

In conclusion, despite their functional similarity, ONSET and *ONSET/X are formally distinct. This fact is further evidence that although the phonological system is significantly shaped by substantive factors, it is fundamentally an abstract formal system.

2.3.2.4 HAVECPLACE

The requirement that a consonant have a supralaryngeal place specification is another of the requirements that is seen to hold specifically of material in a strong position. Parker (2000) demonstrates that a positional version of this constraint, relativized to the syllable onset, is active in Chamicuro, where the glottal consonants [h, ʔ] appear as codas but not as onsets (see §3.4).

The general version of this constraint is given in (40).

(40) HAVECPLACE For all consonants *x*, *x* has a supralaryngeal Place specification

Evidence for general HAVECPLACE can be found in languages that completely lack glottal segments in their inventory, as in many Romance and Australian languages. This constraint is also needed to account for why glottals and pharyngeals, while less marked even than coronals on the universal Place markedness hierarchy *LAB, *DORS >> *COR >> *PHAR (Lombardi 2001), are sometimes dispreferred as epenthetic consonants (as in Axininca Campa, where [t] is the general epenthetic consonant; Payne 1981).

The existence of the constraint HAVECPLACE, and its positional versions, also provides a solution to the apparent variable sonority of glottals. As noted in §2.3.2.2 above, the glottal segments [h, ʔ] sometimes pattern with obstruents, and other times with high-sonority segments. In Pirahã (§3.2.2.4), for example, [h, ʔ] pattern with the class of voiceless obstruents, being preferred over voiced obstruents as onsets in stressed syllables. On the other hand, [h, ʔ] are sometimes derived from other consonants as the outcome of historical change; such diachronic changes are often classified together with cases of lenition (e.g., obstruent voicing or approximantization), so by association the glottals are sometimes categorized as high-sonority segments. Indeed, in Chomsky & Halle (1968), [h, ʔ] are considered to be [-consonantal] because they have no oral constriction. Along these lines, Parker (2000) observes that the ban on glottal onsets in Chamicuro (§3.4) could be explained by an extension of the *ONSET/X subhierarchy if glottals are the highest sonority consonants. Nevertheless, the Pirahã facts, in which the glottal segments [h, ʔ] are preferred as onsets to stressed syllables even over such relatively low-sonority segments as [b, g], cannot be reconciled with the proposal that glottals are high in sonority. The solution to this problem lies in recognizing the independence of sonority and supralaryngeal place. Namely, glottal [h, ʔ] (and pharyngeal obstruents) are different from other obstruents not in sonority, but only because they lack a supralaryngeal place specification, violating HAVECPLACE. Historical change resulting in glottals is debuccalization, not an increase in sonority. The rejection of glottals from certain structural positions, as in Chamicuro, is related not to sonority, but to place.

The theory of **M/str** constraints proposed here entails that, because HAVECPLACE has an **M/str** counterpart, it must be an augmentation constraint. This is in fact the case. According to Stevens (1971), the glottal segments [h, ʔ] differ from other consonants in lacking an area of rapid spectral change at the CV transition point. This is because, with no oral constriction in the consonant, the degree of change in the shape of the oral tract from consonant to vowel is very much smaller than for other consonants. Warner (1998), expanding upon work by Stevens (1971 et seq.), Furui (1986), and others, proposes that periods of rapid change in the speech signal are the most important in speech perception, carrying a large proportion of the information content of the signal; one reason for the importance of such "dynamic cues" is that as the spectral shape of the signal changes, new (unadapted) populations of auditory-nerve fibers respond, as discussed in §2.3.2.3.1 above. Given Warner's (1998) proposal about the importance of dynamic cues in perception, consonants with a supralaryngeal place specification, which have greater dynamic cues at a CV transition, are more perceptually salient than [h, ʔ]. Thus, HAVECPLACE is correctly predicted to pass the Prominence Condition and to form legitimate **M/str** constraints.

2.3.2.5 HTONE

Another attested **M/str** constraint is HTONE/σ́, which requires stressed syllables to have a tone-bearing unit (TBU)[28] that is associated with a high (H) tone (§3.2.1.2).

(41)   HTONE/σ́   For all syllables *x*, if x is a σ́, then a tone-bearing unit associated with *x* bears high tone

It is often proposed that H tone is more prominent than mid (M) and low (L) tone. See for example Meredith (1990), Jiang-King (1996), de Lacy (1999), and the references cited in these works for discussion of phonologically relevant prominence hierarchies among tones, often

[28]This particular formulation of the constraint allows for the choice of syllable or mora as the prosodic category that serves as TBU to be made on a language-specific basis (under OT, by means of different rankings of constraints regulating associations between tones and prosodic units).

described as analogous to the segmental sonority scale. In terms of perceptual prominence, it has been shown that the neural response to a higher-frequency stimulus is more frequency-specific that the neural response to a lower-frequency stimulus (Kluender, Lotto, & Jenison 1995), a factor which may help make higher tones more perceptually salient. Also, since higher-frequency stimuli by definition have more periods per unit time, they have a greater integrated signal intensity than lower-frequency stimuli (J. Kingston, p.c.).

As with HEAVYσ (§2.3.2.1), there is some question as to whether a general version of HTONE/σ́ exists. In this case, the existence of a constraint demanding H tone on all syllables would seem to contradict proposals by, e.g., Stevick (1969) and Pulleyblank (1986) that L is the default or unmarked tone in a two-tone system (similarly for M in a three-tone system). However, when L is argued to be the default or unmarked tone, this is often done on the grounds that L tones are phonologically inert. Myers (1998) takes a different approach to the inertness of L tones, arguing that in at least some languages, such as Chichewa, even surface representations contain only H tones; 'L' actually corresponds to the lack of a phonetic target for tone. As Myers notes, if this proposal is to be implemented within OT, constraints banning an actual phonological specification for L tone must be undominated in the language. Thus, it is not clear that L is universally less marked than H, perhaps removing one objection to the inclusion of a general HTONE constraint in CON. In any case, as noted in the discussion of HEAVYσ (§2.3.2.1), the fundamental claim about **M/str** constraints advanced here — that they are subject to the Prominence Condition — does not crucially depend on the existence of general counterparts for each **M/str** constraint.

The positional augmentation results concerning tone presented in this dissertation are somewhat preliminary (see §4.2.3, §4.3.4.2 for discussion). One topic for future investigation is the relationship between *low* tone and positional augmentation effects. The affinity between H tone and stress is well known; examples are discussed in §3.2.1.2. But if, as many researchers propose, there is a phonologically relevant prominence hierarchy for (simple) tones[29] H > L > M, there is presumably a universal constraint subhierarchy HTONE >> LTONE >> MTONE. Since low tones are more prominent than mid or zero tones, the constraint LTONE would also pass the Prominence Condition, and we would expect to find L-tone augmentation effects as well. The attraction of L tones to stressed syllables (primary and secondary) is in fact attested; see Kang (1997) on metrical structure and tone in Sukuma and Yip (2000) on tone patterns in Chinese languages.[30]

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[29]Contour tones, particularly HL, are often considered to be even more prominent than H. Another area for future investigation is the relationship between contour tones and positional augmentation effects.

[30]de Lacy (1999) also proposes that there is an affinity between L tone and *unstressed* positions. See Yip (2000) for discussion.

2.3.2.6 HAVESTRESS

One more positional augmentation constraint, exemplified by the languages discussed in §4.2.2.1, is the constraint HAVESTRESS/Root.

(42) HAVESTRESS/Root For all syllables *x*, if the head of *x* is affiliated with a root, then *x* bears stress[31]

This markedness constraint, which calls for the presence of stress in a root, does qualify as a prominence-enhancing constraint, as predicted by the Prominence Condition. Stress is a local prominence; an element bearing stress is more prominent than adjacent elements (although the ways in which individual languages give phonetic manifestation to phonologically designated stress may differ, incorporating (sub-phonemic) duration, amplitude, pitch-accents, or combinations thereof; Lehiste 1970, Beckman 1986, Hayes 1995).

The question raised during the discussion of HEAVYσ (§2.3.2.1) and HTONE (§2.3.2.5) is relevant here as well: given that **M/str** constraints have been treated as relativized versions of general (non-positional) markedness constraints, is there any evidence for a general constraint HAVESTRESS, to which HAVESTRESS/Root is a position-specific counterpart?

(43) HAVESTRESS For all syllables *x*, *x* bears stress

With no positional restrictor clause (e.g., 'if the head of *x* is affiliated with a root, then...'; §2.2.2, §2.3.3) included in the formulation of (43), it becomes a constraint demanding that *all* syllables bear stress. There is probably no direct evidence in favor of the existence of such a constraint. There appears to be no stress language in which every syllable of every word bears stress (although there are, for example, tone languages in which every syllable bears a surface tone).

As noted above, however, the question of whether all positional augmentation constraints do have general counterparts is a separate problem from the main proposal here, namely, that all **M/str** constraints are subject to the Prominence Condition. Furthermore, although there may be no evidence *for* general HAVESTRESS, the existence of such a constraint does not actually make incorrect predictions about the typology of stress patterns, because of an independent requirement that stress be culminative (Trubetzkoy 1939; Liberman 1975; Hyman 1977; Hayes 1995); in other words, that every prosodic constituent have exactly one head. Where main (word) stress is concerned, this means that every PrWd has exactly one head foot, which has exactly one head syllable, and this syllable bears the main stress of the PrWd.

[31]See §2.3.3 below on the use of prosodic heads to determine affiliations between morphological and prosodic categories.

The requirement that stress be culminative is apparently never violated.[32] It must in fact be actively enforced, either by a universally undominated constraint or by limits on GEN (the function that generates the set of competing output candidates for each input; Prince & Smolensky 1993), because when a complex prosodic constituent is composed of two or more elements each of which contributes a top-level stress, all but one of the stresses is always demoted, if not deleted entirely (as captured in, e.g., the Nuclear Stress Rule of Chomsky & Halle 1968). For expositional clarity, the following constraint can be used to model the mandatory culminativity of stress (with the understanding that it might actually reflect limits on the form of candidates that GEN can emit rather than being an individual member of the set of constraints).[33]

(44) CULMINATIVITY Every prosodic constituent has exactly one head

The inclusion of universally undominated CULMINATIVITY in CON (or in GEN), which is independently needed to explain why a form with multiple input stresses will always surface with exactly one output stress, can also account for why no language has stress on every syllable, even if general HAVESTRESS is in fact part of CON.

One final point about HAVESTRESS is that, while all of the HAVESTRESS constraints considered in §4.2 are for main stress, presumably there are HAVESTRESS constraints corresponding to stress at all relevant levels of the prosodic hierarchy, in particular, foot-level (secondary) stress. Finding evidence for general and positional HAVESTRESS constraints at the foot level is a topic left for future investigation.

2.3.2.7 Summary

This section (§2.3.2) has examined a number of markedness constraints that have attested **M/str** counterparts (see chapters 3 and 4). Each of these constraints has been shown to be an augmentation constraint, a constraint that calls for some perceptually prominent characteristic. Thus, the Prominence Condition, a constraint filter that passes **M/str** constraints only when they are built from augmentation constraints, makes correct predictions about which markedness constraints can be relativized to strong positions.

Another objective of this section has been to give each augmentation constraint an explicit formulation that unambiguously identifies the constraint focus. As explained in §2.2.2 above, it is the nature of the focus that determines the strong positions to which a given

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[32]Claims have occasionally been made in the literature for words with multiple primary stresses, for example by Voegelin (1935) on Tübatulabal, Dixon (1977) on Yidin^y, and Woodbury (1987) on Central Alaskan Yupik. However, such cases are controversial; see Hayes 1995 for discussion.

[33]The constraint encapsulation CULMINATIVITY invoked here is based on that in Alderete (1999b), except that Alderete considers CULMINATIVITY to be potentially violable.

constraint can be relativized. The following section (§2.3.3) now examines what happens when the augmentation constraints presented above are combined with the members of the set of strong positions. Many of the resulting positional constraints are legitimate constraints. Others, however, are meaningless because they involve a "domain mismatch," that is, a strong position that, because of its size or character, is not compatible with the focus of the constraint in question.

2.3.3 Augmentation constraints and strong positions

This section examines the predictions that are made when the **C**/*str* constraint schema, which forms position-specific constraints (§2.2.2), is applied to the strong positions from §1.3.1 and the augmentation constraints from §2.3.2. All of the **M/str** constraints thus formed are legitimate constraints according to the Prominence Condition, because they are relativized versions of augmentation constraints. However, not all of these constraints are meaningful, because in some cases the constraint focus, which plays a crucial role in determining the formulation of any relativized version of the constraint, is not compatible with a particular strong position. This kind of incompatibility is termed a *domain mismatch* (§2.2.2).

First, the five strong positions stressed syllable, long vowel, onset, initial syllable, and root are explicitly characterized, so that their semantic contribution to the positional restrictor *if/then* clauses introduced by the **C**/*str* schema can be specified. Then, a chart is presented that shows all the possible combinations of the augmentation constraints from §2.3.2 with these strong positions. Among the positional augmentation constraints thus generated, meaningful constraints are distinguished from domain mismatches. The chart also indicates whether or not the expected **M/str** constraints are attested (and if so, where in chapters 3 and 4 they are discussed). Several of the expected **M/str** constraints for the psycholinguistically strong positions, initial syllable and root, are conspicuously unattested, but these are the **M/Ψstr** constraints that the Segmental Contrast Condition, the constraint filter discussed in §2.4 below, predicts not to be included in CON.

The **C**/*str* schema, introduced in §2.2.2, is repeated in (45). This is the constraint schema that constructs all relativized constraints, including **M/str** constraints.

(45) The **C**/*str* schema

C/*str*	For all *y*, if *y* is a *str*, then **C** holds of *y*
	where *y* is an element in the focus of the constraint **C**

As described above, the **C**/*str* schema has been given this particular characterization so that the formulation of any relativized constraint is predictable from the formulation of the general constraint **C** and the nature of the strong position *str*. Formulations of the general versions of the augmentation constraints under investigation here have been presented in §2.3.2. In (46) and the discussion that follows, explicit characterizations are now given to the strong positions, so that their contribution to the formulation of a given **M/str** constraint can also be made explicit. (See §2.4.2 for further discussion of the division between phonetically and psycholinguistically prominent positions, introduced in §1.3.1.)

(46) Strong positions as positional restrictor clauses

(a) Phonetically strong positions

Position	*Restrictor clause*	*Compatible constraint foci*
σ́	...if *x* is a σ́, then...	syllable
Vː	...if *x* is a Vː, then...	segment
Onset	...if *x* is $C_{[+release]}$, then...	segment

(b) Psycholinguistically strong positions

Position	*Restrictor clause*	*Compatible constraint foci*
σ_1	...if *x* is the leftmost σ whose head is affiliated with MWd *m*, then...	syllable
Root	...if [the head of] *x* is affiliated with a root, then...	Any focus is compatible

The formalization of the phonetically strong positions (46a) as positional restrictor clauses is fairly straightforward. *Stressed syllable* (σ́) is intended to mean "head syllable of the head foot of the prosodic word", that is, the syllable that bears main stress.[34] *Long vowel* (Vː) is intended to mean "vowel associated with more than one mora". Finally, as noted in §1.3.1, the phonetically strong position abbreviated as *onset* for the sake of notational convenience is more accurately identified as "released consonant" (Kingston 1985, 1990; Lombardi 1991, 1999). Given these characterizations, constraints that can be meaningfully relativized to these positions are those whose focus refers to a syllable, a segment, and a segment respectively, as indicated in (46a).

The formalization of the psycholinguistically strong positions (46b) requires somewhat more discussion. The complicating factor here is that both of these positions are morphologically defined; the root obviously so, and the initial syllable because it is the initial syllable of the

[34]As noted in §1.3.1, footnote 7, other prosodic heads — including the head syllables of non-head feet (σ̀) and phrasal heads — are probably also to be included in the set of strong positions. However, in the present discussion, attention is restricted to main-stress syllables.

morphological word (MWd) that is the relevant strong position (§4.4). Because morphological structure and prosodic structure are on different "planes" of phonological representation, these two kinds of structure can be directly related only with reference to the segments that they share (as noted in various discussions of morphological-prosodic alignment constraints, especially McCarthy & Prince 1993a:89; see also Kager 1999:11). Thus, when these morphologically defined positions need to be related to prosodic constituents, this can be done by way of the segments that serve as heads of those prosodic constituents (see also McCarthy 2000ab on faithfulness to prosodic heads through segmental correspondence). The specific examples that follow help clarify this proposal.

First, in accordance with the use of prosodic heads to mediate between prosodic and morphological structure, the *initial syllable* must be defined in such a way as to relate the syllable and MWd aspects of this position through the (terminal) head of the syllable, since this is a segment, and only segments can have a morphological affiliation. Thus, the initial syllable of MWd *m* is identified in (46b) as <u>the leftmost syllable whose head is morphologically affiliated with *m*</u>. Constraints that can be meaningfully relativized to this position are, as shown in (46b), those whose focus refers to a syllable.

The other psycholinguistically strong position, the *root*, is different from all other strong positions, including the initial syllable, in that it is defined entirely by morphological affiliation, with no additional reference to phonological elements of any size. Therefore, no **M/Root** constraint is predicted to result in a domain mismatch, regardless of the nature of the focus of **M**. However, if a constraint whose focus is a prosodic constituent (such as HAVESTRESS (43), for which the focus is a syllable) is to be relativized to the strong position root, this also must be done through reference to the segment that is the (terminal) head of the prosodic constituent in question. In such a case, the phrase 'the head of' is automatically included in the positional restrictor clause for roots, as indicated with brackets in (46b).[35]

Given the constraint formulations in §2.3.2 above and the characterizations of the positional restrictor clauses in (46), it is possible to predict which constraints can be relativized to which positions without giving rise to a domain mismatch. The chart in (47) shows all possible combinations of the constraints and positions under consideration. For each constraint, the types of elements referred to in the constraint's focus are indicated with the notation • *foc*. **M/str** combinations that involve a domain mismatch are identified with shaded cells and the

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[35]Because an **M/Root** constraint with a prosodic category as its focus must be relativized in this way — through reference to the head of the syllable — a prediction is made that a syllable with an epenthetic vowel for its head, even if it contains other root-affiliated segments, will not be subject to the **M/Root** constraint. For example, HAVESTRESS/Root ('for all syllables *x*, if *x* is affiliated with a root, then *x* bears stress') is predicted not to be sensitive to epenthetic vowels in roots. This prediction appears to be borne out in Chukchee (Krause 1979), where roots preferentially bear stress unless the only vowels they contain are epenthetic schwas, and there is no general ban on stressed schwa.

notation ***DM***. For each non-mismatch, if the constraint is attested in the language examples discussed in chapters 3 and 4, the corresponding cell is marked with ✓ and a cross-reference to the relevant examples is given. If the constraint is not attested, the cell is marked with one of three codes (*SCC*, *vac[uous]*, or *note*) and the constraint is given further discussion below the chart.

(47) Predicted positional augmentation constraints

	(a) **M/Φstr**			(b) **M/Ψstr**	
	σ́	Vː	onset	σ_1	root
HEAVYσ • *foc:* σ	✓ **§3.2.1.1**	***DM***	***DM***	*(SCC)*	*(SCC)*
*PEAK/X • *foc:* seg, σ	✓ **§3.2.1.3**	✓ **§3.3**	*(note)*	*(SCC)*	*(SCC)*
ONSET • *foc:* σ	✓ **§3.2.2**	***DM***	***DM***	✓ **§4.2.1.1**	*(SCC)*
*ONSET/X • *foc:* seg, σ	✓ **§3.2.2**	(✓) *(vac.)*	*(note)*	✓ **§4.2.1.2**	*(SCC)*
HAVECPLACE • *foc:* C	***DM***	***DM***	✓ **§3.4**	***DM***	*(SCC)*
HTONE • *foc:*σ	✓ **§3.2.1.2**	***DM***	***DM***	(*SCC?*) (§4.2.1.3)	(*SCC?*) (§4.2.2.3)
HAVESTRESS • *foc:*σ	(✓) *(vac.)*	***DM***	***DM***	*(note)* (§4.2.1.3)	✓ **§4.2.2.1**

The special cases indicated in the chart in (47) are as follows. A number of **M/Ψstr** constraints are marked *SCC*: HEAVYσ/σ_1, HEAVYσ/Root, [*PEAK/X]/σ_1, [*PEAK/X]/Root, ONSET/Root, [*ONSET/X]/Root, and HAVECPLACE/Root. These are all well-formed constraints by the **C**/*str* schema, and they pass the Prominence Condition. Nevertheless, they are excluded from CON because they fail to pass the Segmental Contrast Condition, a constraint filter on **M/Ψstr** constraints that is discussed in §2.4 below and in §4.3. (HTONE/σ_1 and HTONE/Root may also be blocked by the Segmental Contrast Condition; see §4.3.4.2 for discussion.)

Two of the **M/str** constraints in (47) are marked *vacuous*: [*ONSET/X]/Vː and HAVESTRESS/σ́. These constraints would have the formulations in (48).

(48) (a) [*ONSET/X]/Vː For every segment *a* that is the leftmost pre-moraic segment of some syllable *x*, if *a* is a Vː, then |*a*| < X

where |*y*| is the sonority of segment *y*
X is a particular step on the segmental sonority scale

(b) HAVESTRESS/σ́ For all syllables *x*, if *x* is a σ́, then a *x* bears stress

As can be seen in (48), these two constraints are not technically domain mismatches, because there is no formal incompatibility between the focus of **M** and the restrictor clause introduced by the strong position. However, they are like domain mismatches in that they are tautological — they are vacuously satisfied by every possible candidate. [*ONSET/X]/Vː is always satisfied because no segment can simultaneously be non-moraic and bimoraic. HAVESTRESS/σ́ is always satisfied because it simply demands of a stressed syllable that it be a stressed syllable. Since these two constraints are tautological, they can play no active role in the phonologies of individual languages (and may even be ruled out by a constraint filter against tautological constraints; see the remarks on domain-mismatch cases in §2.2.2).

Finally, there are three constraints in (47) marked *note*: HAVESTRESS/σ_1, [*ONSET/X]/Ons, and [*PEAK/X]/Ons. These constraints are predicted by the model to exist, but (at this time) it is not clear that there is evidence of their activity in the phonology of any language. These constraints are predicted to exist because they are well-formed according to the **C**/*str* schema, they pass the Prominence Condition, they pass the Segmental Contrast Condition (see §2.4 below), and, as shown in (49), they do not involve a domain mismatch.

(49) (a) HAVESTRESS/σ_1 For all syllables *x*, if *x* is the leftmost σ whose head is affiliated with MWd *m*, then *x* bears stress

(b) [*ONSET/X]/Ons For every segment *a* that is the leftmost pre-moraic segment of some syllable *x*, if *a* is $C_{[+release]}$, then |*a*| < X

where |*y*| is the sonority of segment *y*
X is a particular step on the segmental sonority scale

(c) [*PEAK/X]/Ons For every segment *a* that is the head of some syllable *x*, if *a* is $C_{[+release]}$, then |*a*| > X

where |*y*| is the sonority of segment *y*
X is a particular step on the segmental sonority scale

HAVESTRESS/σ_1 (49a) is a constraint that requires the initial syllable to bear stress. As noted in §4.2.1.3, there are indeed languages with mandatory initial stress; the problem is only that it may be impossible to distinguish HAVESTRESS/σ_1 empirically from ALIGN-L constraints on stress.

[*ONSET/X]/Ons (49b) is a constraint subhierarchy whose members demand that a syllable "onset" (formally, the leftmost pre-moraic segment) be low in sonority if it is an instance of the strong position "onset" (formally, a released consonant). The leftmost pre-moraic segment of a syllable will nearly always be a released consonant. As a result, in most languages, [*ONSET/X]/Ons will assign exactly the same violation marks as general *ONSET/X. Only in a language where the leftmost pre-moraic segment is not always released (as might be the case in an obstruent-obstruent onset cluster, as argued for example by Steriade 1997) can the effects of [*ONSET/X]/Ons and general *ONSET/X be distinguished; such a case is not included in the languages considered in chapters 3 and 4.

[*PEAK/X]/Ons (49c) is a constraint subhierarchy whose members demand that if a syllable peak consists of a released consonant, that peak must be high in sonority. Again, the effects of this constraint could be distinguished from those of general *PEAK/X only in a language that makes a distinction between consonantal syllable peaks that are released and consonantal syllable peaks that are not released, and a relevant situation has not been found among the languages considered here.

Thus, the three constraints marked *note* in (47) are constraints that are predicted by the model to exist, but either overlap to a great extent with other attested constraints, or would potentially be active in only a very limited set of circumstances; it is not surprising that empirical evidence for these constraints has yet to be found.

The rest of the formally possible **M/str** constraints in (47), marked with ✓, are empirically attested, just as the model predicts. Languages in which these **M/str** constraints play an active role are discussed in the sections of chapters 3 and 4 that are indicated in the corresponding cells in the chart.

2.3.4 Summary

This section has implemented the first proposed restriction on **M/str** constraints, the Prominence Condition, as a filter in the Schema/Filter model of CON. The Prominence Condition accepts an **M/str** constraint only if the corresponding general **M** constraint is an augmentation constraint (calling for the presence of perceptually prominent characteristics). This filter has been shown to make correct predictions about which **M** constraints are seen to have **M/str** counterparts in the languages discussed in chapters 3 and 4, because all the general **M** constraints from which the attested **M/str** constraints are built are indeed augmentation constraints. Finally, all the possible combinations of these augmentation constraints with the members of the set of strong positions have been enumerated, and the inventory of **M/str** constraints predicted by the model has been shown to match well with the inventory of attested **M/str** constraints — once the effects of the Segmental Contrast Condition, the constraint filter that is the topic of the following section, have also been taken into account.

2.4 M/Ψstr constraints and the Segmental Contrast Condition

Up to this point, the discussion has focused on general properties of augmentation constraints and strong positions, and thus on the predictions that the model makes about **M/str** constraints in general. However, not all strong positions obtain their privileged status from the same kinds of substantive considerations. As originally proposed by Beckman (1997, 1998) and Casali (1996, 1997), there are two classes of strong positions. *Phonetically strong positions*, abbreviated *Φstr*, are those positions that have particularly salient phonetic cues to the recovery of phonological contrasts; examples discussed here are the stressed syllable, the long vowel, and the onset (released consonant). *Psycholinguistically strong positions*, abbreviated *Ψstr*, are positions that are important in speech processing; specifically, it is proposed here that psycholinguistically strong positions are those positions that play an important role in the *early stages* of word recognition (see §2.4.2 below and §4.3.1 on this distinction). Thus, psycholinguistically strong positions include the initial syllable and the morphological root, but, crucially, not the stressed syllable.

Because only psycholinguistically strong positions are directly involved in early-stage word recognition (§4.3), there are substantive pressures on these strong positions that are not relevant for phonetically strong positions. One such pressure is the drive to avoid the neutralization of phonological contrasts specifically in these positions, since this would make word recognition less efficient without reducing the overall complexity of the language's inventory of contrastive categories (§4.3.5). Another substantive pressure relevant for psycholinguistically strong positions is the drive to facilitate what is known as segmentation of the speech stream, that is, division of the incoming acoustic signal into words so that word recognition can be accomplished (see §4.3.4.1.3 on the difficulties of word segmentation in speech perception).

These two pressures are formalized here as a constraint filter, the Segmental Contrast Condition, which evaluates **M/Ψstr** constraints — augmentation constraints relativized to psycholinguistically strong positions. The Segmental Contrast Condition blocks **M/Ψstr** constraints from inclusion in CON if their satisfaction would neutralize contrasts that are important in early-stage word recognition (i.e., "segmental" contrasts, as distinct from "prosodic" contrasts, but see §4.3.4.2 on the possibility that tone patterns with segmental contrasts), unless the property required by the constraint is one that aids in left-edge demarcation of words.

With the Segmental Contrast Condition in place, the model predicts that certain **M/Ψstr** constraints that pass the Prominence Condition (§2.3.1), and do not involve any domain mismatch between the constraint focus and the strong position (§2.3.3), will nevertheless fail to be part of CON if they call for the neutralization of psycholinguistically relevant contrasts. The differences between the columns for stressed syllable (a phonetically strong position) and initial syllable (a psycholinguistically strong position) in (47) above demonstrate the accuracy of this prediction. The two strong positions are both syllable-sized, so they are formally compatible with the same set of augmentation constraints (as far as the **C**/*str* schema and domain-mismatch avoidance are concerned). Nevertheless, there are more **M/$\acute{\sigma}$** constraints than **M/σ_1** constraints attested. Likewise, the absence of feature-related **M/Root** constraints in (47) matches the predictions made by the Segmental Contrast Condition.

This section presents the Segmental Contrast Condition and discusses its implications for the theory of positional augmentation constraints. (More detailed discussion of the nature of the Segmental Contrast Condition, and a review of the psycholinguistic evidence that supports the characterization of this constraint filter as it is given here, are provided in §4.3; cross-references to relevant subsections of §4.3 are given throughout this section.) §2.4.1 presents a characterization of the Segmental Contrast Condition as a constraint filter, describes how constraints can be tested for compliance with this filter, and identifies the **M/Ψstr** constraints that pass the filter. §2.4.2 gives an overview of the difference between phonetically and psycholinguistically strong positions that is fundamental to the Segmental Contrast Condition (this difference is discussed in greater detail in §4.3). A preliminary proposal is also presented concerning another domain of phonology that can be fruitfully analyzed in terms of a constraint filter distinguishing between phonetically and psycholinguistically strong positions: the close relationship between neutralization avoidance in phonetically strong positions and the specific phonetic characteristics of those positions ("licensing by cue"), which has been investigated especially in the work of Steriade (1993, 1995, 1997, 1999ab).

2.4.1 The Segmental Contrast Condition

The Segmental Contrast Condition is a constraint filter on **M/Ψstr** constraints that models the substantive requirements on psycholinguistically strong positions described above: the pressure to avoid the neutralization of contrasts in these psycholinguistically important positions, and the pressure to facilitate segmentation of the speech stream by demarcating the left edges of words. Because these two substantive pressures interact, they are modeled as a single, two-part constraint filter.

(50) *Segmental Contrast Condition*

If a constraint is of the form **M/Ψstr**, then it must meet one of the following two conditions:

I. Satisfaction of the **M** constraint from which the **M/Ψstr** constraint is built does not alter features that are distinguished in early-stage word recognition.

or

II. **Ψstr** is σ_1, and satisfaction of the **M/Ψstr** constraint serves to demarcate the left edge of σ_1.

M/Ψstr constraints are tested against clause I of the Segmental Contrast Condition as follows. From an arbitrary input, two candidates are generated that are "minimally different" with respect to their faithfulness violations (as defined for the Prominence Condition in §2.3.1

above), such that one satisfies the general version of **M** but the other violates it. If the two candidates, while being *perceived*, cause the same pattern of lexical activation — that is, cause the same set of lexical entries to be activated to the same extent — then the contrast neutralized by **M** is irrelevant for early-stage word recognition, and the **M/Ψstr** constraint passes clause I of this filter.

Constraints are tested against clause II of the Segmental Contrast Condition in a similar manner. Again, from an arbitrary input two minimally different candidates are generated such that one satisfies **M/Ψstr** (the positional version of the constraint this time, since it is a particular position, namely initial syllable, to which clause II is sensitive) and the other violates it. If **Ψstr** is something other than initial syllable, then **M/Ψstr** fails clause II immediately. If **Ψstr** is initial syllable, and the leftmost segments of the two candidates differ, then the **M/Ψstr** constraint passes clause II.[36]

Like the Prominence Condition, discussed in §2.3 (and like the Inductive Grounding Principle of Hayes 1999a), the Segmental Contrast Condition is a filter that evaluates formally possible constraints by using extra-phonological information. In this case, it is information from the processing and word-recognition system that determines which potential constraints should be included in CON. It should be noted that the Prominence Condition and the Segmental Contrast Condition are not ordered or ranked in any way, as is true of constraint filters in general (i.e., constraint filters are not like the constraints of an OT grammar). Any constraint that fails any of the filters is simply not included in CON.

The Segmental Contrast Condition makes explicit predictions about what kinds of augmentation constraints can have **M/Ψstr** counterparts. Namely, **M/Ψstr** constraints are not permitted to manipulate phonological contrasts that are involved in early-stage word recognition, with the exception of onset manipulation in initial syllables, which is allowed by clause II. Since stress, even though it can be phonologically contrastive, is not crucially involved in this aspect of word recognition (§4.3.4), augmentation constraints that manipulate stress in psycholinguistically strong positions are predicted to exist. In fact, there is empirical evidence in support of the existence of HAVESTRESS/Root (§4.2.2.1), and evidence that is compatible with the existence of HAVESTRESS/σ_1 (§4.2.1.3).

It is necessary also to consider the implications of the Segmental Contrast Condition for positional augmentation constraints that manipulate tone, such as HTONE/σ_1 and HTONE/Root.

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[36]Clause II of the Segmental Contrast Condition is formulated to be as general as possible: an **M/Ψstr** constraint passes clause II if its satisfaction affects the left edge of σ_1, with no further specification as to how the left edge must be affected. As a result, constraints that manipulate the left edge of σ_1 in ways unrelated to prominence enhancement will pass clause II just as the legitimate, empirically attested ONSET/σ_1 and [*ONSET/X]/σ_1 will. However, any left-edge-effecting constraint that is not related to prominence enhancement will fail to pass the Prominence Condition (§2.4.1) and will be excluded from CON for that reason.

If tone is lexically contrastive in a given language, then it is possible to have two lexical entries that are phonologically distinguished only by tone. However, psycholinguistic results reported to date are not conclusive about whether tone is like segmental contrasts, in that it distinguishes lexical entries during early-stage word recognition, or whether tone is like stress, in that it does not. Until the role of tone in word recognition is better understood, it is not clear whether HTONE/σ_1 and HTONE/Root pass the Segmental Contrast Condition. See §4.3.4.2 for discussion.

On the other hand, augmentation constraints that manipulate segmental contrasts, namely, HEAVYσ, *PEAK/X, ONSET, *ONSET/X, and HAVECPLACE, all fail clause I of the Segmental Contrast Condition because their satisfaction does affect segmental featural contrasts. Therefore, these constraints do not have **M/Root** counterparts at all, and only ONSET and *ONSET/X have **M/**$\boldsymbol{\sigma_1}$ counterparts, because these are the only **M/**$\boldsymbol{\sigma_1}$ constraints that are relevant for the left edge of the initial syllable[37] and therefore pass clause II of the filter.

In summary, there is a tension inherent in the substantive considerations related to **M/Ψstr** constraints. On the one hand, psycholinguistically strong positions, like all strong positions, would be perceptually enhanced by the satisfaction of augmentation constraints relativized to these positions. On the other hand, when an augmentation constraint is satisfied, some potential phonological contrast is neutralized — the perceptually salient characteristic mandated by the constraint is always present, so the presence versus absence of that characteristic can no longer serve as the basis for a contrast — and the neutralization of segmental contrasts specifically in psycholinguistically strong positions is detrimental to efficient word recognition. The inclusion of the Segmental Contrast Condition in the Schema/Filter model of CON protects psycholinguistically strong positions from segmental-contrast neutralization, including neutralization for purposes of augmentation, except where augmentation would help in left-edge demarcation for segmentation of the speech stream.

2.4.2 Classifying strong positions

The Segmental Contrast Condition, presented in the preceding section, is a constraint filter that captures certain substantive requirements holding of markedness constraints relativized to psycholinguistically strong positions. These substantive requirements have their basis in the special status of psycholinguistically strong positions in early-stage word recognition. In this section, the distinction between psycholinguistically and phonetically strong positions is discussed, and the proposal that only initial syllable and root qualify as psycholinguistically strong positions is defended (see also the more detailed discussion in §4.3.3). Consideration is also given to another phonological phenomenon that distinguishes phonetically and psycholinguistically strong positions: "licensing by cue" effects (Steriade 1993, 1995, 1997, 1999ab) in resistance to positional neutralization.

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[37]HAVECPLACE/σ_1 might look like another left-edge-related constraint, but since the focus of HAVECPLACE is a segment, relativizing this constraint to the initial syllable leads to a domain mismatch (47).

2.4.2.1 Psycholinguistically strong positions

The definition of a psycholinguistically strong position given here is based on the proposals of Beckman (1997, 1998) and Casali (1996, 1997), who recognize the phonologically privileged status of these positions in their ability to resist positional neutralization. These researchers state (emphasis added),

> Positions which are psycholinguistically prominent are those which bear the heaviest burden of *lexical storage, lexical access and retrieval, and processing*: root-initial syllables, roots and, to some degree, final syllables. (Beckman 1998:1)
>
> ...preferential preservation of word-initial material may be related to the crucial function initial segments play in *speech processing*... (Casali 1997:494)

However, the proposal made here is more specific than Beckman's and Casali's proposals: it is the importance of a particular position specifically for *early-stage word recognition*,[38] not just for speech processing in general, that gives it the status of a psycholinguistically strong position. Thus, initial syllables and roots qualify as psycholinguistically strong positions, but stressed syllables do not, even though they are clearly not irrelevant for speech processing (§4.3.4.1). Crucially, the involvement of stressed syllables in speech processing is different and less direct. Stress patterns are used in later stages of word recognition to find the best match between the incoming signal and one of the lexical items that has already been activated in the early stage, and stressed syllables are used in some languages to help with segmentation of the speech stream during processing. However, early-stage word recognition is not carried out with direct reference to stressed syllables. Justification for this claim is provided throughout §4.3, most explicitly in §4.3.4.

2.4.2.2 Phonetically strong positions

The theories of positional faithfulness developed by Beckman (1997, 1998) and Casali (1996, 1997), following work by, e.g., Steriade (1993, 1995, 1997) and Jun (1995), also recognize certain positions that have a special ability to license contrasts, or resist neutralization processes, because they are positions that have intrinsic *phonetic* salience. These positions include the stressed syllable, the long vowel, and the syllable onset (released consonant).

As discussed extensively by Steriade (1993, 1995, 1997, 1999ab; see also, e.g., Kingston 1985, 1990 and Lombardi 1991, 1999), there is a close relationship between the kind of salience that a phonetically strong position has and the kinds of contrasts that it has a special ability to license. (Preliminary discussion of how this relationship could itself be modeled in the

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[38]The term *early-stage word recognition* is used here to indicate the stage of speech processing in which a set of lexical entries that are similar to the incoming acoustic signal is initially activated (see §4.3.1).

Schema/Filter theory of CON is found in §2.4.2.3 below.) For example, onset consonants are characteristically released into a following sonorant, so they are better able than characteristically unreleased consonants (such as syllable codas) to license contrasts for which auditory cues are found in the consonantal release — e.g., voicing, aspiration, or many place features. However, syllable onsets (and released consonants in general) show no special licensing ability for retroflexion, because, Steriade (1993 et seq.) argues, the most salient perceptual cues for retroflexion are found in the VC transition, not in the consonantal release.

While the relationship between phonetically strong positions and featural licensing abilities (i.e., possible positional faithfulness constraints) is highly restricted, however, the relationship between these positions and augmentation constraints is remarkably free. As observed in the chart in (47) in §2.3.3, phonetically strong positions are eligible for any kind of positional augmentation constraint that can legitimately be relativized to a position of that particular size. Most strikingly, a phonetically strong position can undergo augmentation processes that add prominent properties completely unrelated to the properties that make that particular position a salient one.[39] For example, the position stressed syllable is prominent for phonetic reasons related to properties of vowels (or rimes), such as increased duration or amplitude relative to unstressed syllables. Nevertheless, stressed syllables undergo augmentation processes involving *consonantal* features, i.e., ONSET/σ́ and [*ONSET/X]/σ́.

Thus, it can be concluded that there are no restrictions on positional augmentation constraints for phonetically strong positions, other than the basic Prominence Condition, which applies to all **M/str** constraints. In terms of the Schema/Filter model of CON, this pattern supports the proposal that there are no filters that apply specifically to **M/Φstr** constraints. Furthermore, the Segmental Contrast Condition is predicted not to apply to these positions, since they are not directly relevant in early-stage word recognition. This prediction is met, since **M/Φstr** constraints related to segmental contrasts (HEAVYσ/σ́, [*PEAK/X]/Vː, [*PEAK/X]/σ́, ONSET/σ́, [*ONSET/X]/σ́, HAVECPLACE/Onset) are well attested.

2.4.2.3 Excursus: "Licensing by Cue" as a filter on F/Φstr constraints

Given that there is a formal distinction between phonetically and psycholinguistically strong positions that is relevant for one constraint filter, the Segmental Contrast Condition, it is to be expected that other constraint filters might also make use of this distinction. One plausible case has to do with the way that positional *faithfulness* effects — the special resistance of material in strong positions to featural neutralization — seem to differ between phonetically and

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[39]As noted in Chapter 1, this is evidence for the status 'phonetically strong position' as an abstract, formal designation that is distinct from the phonetic properties that allow a position to qualify as strong.

psycholinguistically strong positions. When positional faithfulness constraints[40] are high ranking, they allow strong positions to "license features," that is, to resist neutralization processes that affect other positions. Therefore, an examination of the contrasts that are permitted only in a particular strong position gives an indication of the kinds of positional faithfulness constraints that exist for that position.

For positional augmentation constraints, as just seen, there is a filter specific to **M/Ψstr** constraints that restricts the possibilities for augmentation in psycholinguistically strong positions. For positional faithfulness constraints, the reverse pattern is observed: the phonetically strong positions are particularly restricted in their ability to form **F/Φstr** constraints, whereas no such restriction is found for **F/Ψstr** constraints. Although a detailed investigation of positional faithfulness effects sorted by type of position is not possible here, this section presents a preliminary proposal for how restrictions on **F/Φstr** constraints can be modeled in the Schema/Filter model of CON. A filter, the Feature Licensing Condition, can be used to rule out formally possible but apparently unattested positional faithfulness constraints for phonetically strong positions.

As noted in the preceding section, Steriade (1993, 1995, 1997, 1999ab) demonstrates that the special licensing abilities of syllable onsets/released consonants are restricted to features whose salient cues are found in the consonantal release, such as place, voicing, or aspiration. Consonants of this type have no special ability to license features such as retroflexion or preaspiration, since the cues to those features are found at the transition *into* a consonant, and simply being released does not mean that a consonant is in an environment (i.e., postvocalic) where cues for retroflexion and preaspiration are found.

A similar result emerges when the positional licensing effects compiled by Beckman (1998) for the phonetically strong position stressed syllable and the psycholinguistically strong position initial syllable are compared, as in (51).

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[40]As discussed in §5.2, several formally distinct proposals have been made for analyzing positional neutralization effects: **F/str** constraints, **M/wk** constraints, and COINCIDE(α,**str**) constraints. **M/wk** constraints are not considered here because there are problems inherent in adopting constraints that refer directly to weak positions; see §1.3.2. **F/str** and COINCIDE constraints, while formally different in how they assess violations and in how they are used to account for positional neutralization effects, both refer only to strong positions. Since the discussion in this section shows that there are substantive restrictions on **F/Φstr** constraints in a system that accounts for positional neutralization with **F/str** constraints, this would obviously translate into substantive restrictions on COINCIDE(α,**Φstr**) constraints if the other approach to positional neutralization is taken. In either case, the same substantive restriction must be captured in a filter on the relevant *Φstr*-related constraints.

(51) Feature licensing by σ́ and σ_1 (from Beckman 1998)

	Stressed syllable (Φstr)		*Initial syllable (Ψstr)*	
V features	Tone	(Copala Trique)	Length	(Dhangar-Kurux)
	Height	(Italian)	Height	(Shona)
	Color	(English)	Color	(Turkic)
	Nasality	(Guaraní)	Nasality	(Dhangar-Kurux)
C features	*none*[41]		Implosives	(Doyayo)
			Labiovelars	(Doyayo)
			Secondary arctic.	(Shilluk)
			Clicks	(!Xóõ)

This chart supports the claim that a phonetically strong position can only have a special faithfulness relationship with a feature for which that position characteristically possesses salient cues. Since the phonetic prominence of a stressed syllable has to do with the duration, amplitude, and/or pitch contour of its rime, all of which increase the perceptibility of vowel features, there are stressed-syllable positional faithfulness constraints for vowel features but not for consonantal features. However, the initial syllable, a psycholinguistically strong position, has no such restriction; a variety of contrasts, involving both consonant and vowel features, are licensed by initial syllables in the languages listed in (51).

Although there is a close relationship between a phonetically strong position and the features for which it has a special licensing ability, there is reason to believe that this relationship is not a direct one. First, evidence from positional augmentation in phonetically strong positions shows that the status of 'phonetically strong position' is an abstract formal property that can be manipulated by the phonology in ways that are unrelated to the phonetic source of the position's special status. As discussed in §2.3.3 and §2.4.2.2 above and in Chapter 3, an augmentation constraint can be relativized to a phonetically strong position even when the prominent property manipulated by the augmentation constraint is not related to the characteristic phonetic salience of the position. For example, even though the stressed syllable is phonetically salient based on its vowel- or rime-related properties, this strong position is affected by positional augmentation constraints like ONSET/σ́ and [*ONSET/X]/σ́, which do not affect vowels or rimes. This fact

[41]Actually, Beckman (1998) does list one example that might fit in this box: the Otomanguean language Copala Trique, which has final stress. The description of this language in Hollenbach (1977) suggests that certain consonant types are restricted to the onset of the final syllable, but there also appear to be allophonic alternations (suggestive of particularly *low*-ranking faithfulness) that occur only in this position as well. Further information is needed to determine whether it is the presence of stress per se that influences these consonant patterns; the otherwise striking restriction of Beckman's (1998) stressed-syllable licensing examples to vocalic features suggests that another explanation may be available for Copala Trique.

indicates that the formal phonological system has access to the abstract information *σ́ is a phonetically strong position*, rather than to the phonetically transparent information *σ́ has good vowel- and rime-based cues*.

Second, the filters that have been discussed so far — the Prominence Condition, the Segmental Contrast Condition, and also the Inductive Grounding Principle of Hayes (1999a) — all show that substantive considerations influence the contents of CON through constraint filters that use extra-phonological information, from domains such as perception, processing, and articulation, to accept or reject formally possible constraints. This supports the proposal, advanced also by Hayes (1999a), that constraint construction itself is a formal process that freely generates constraints without regard to functional or substantive considerations — such substantive considerations being imposed exclusively by the constraint filters. If it is true that constraint construction is a purely formal process, then there is no way for the constraint-construction module to know that a positional faithfulness constraint like IDENT[Vheight]/σ́ is a possible constraint, but something like IDENT[voice]/σ́ is not.

Thus, if the relationship between phonetically strong positions, like the stressed syllable, and the features for which they have special licensing abilities, in this case vowel-related features, is not supplied directly by the phonetics, then there must be some explanation for the fact that positional faithfulness constraints for phonetically strong positions are restricted to those involving features whose perceptual cues are particularly salient in the position in question. This is precisely the role played by filters in the Schema/Filter model. A full account of the restricted positional licensing behavior shown by phonetically strong positions would therefore involve an additional filter, the Feature Licensing Condition, stated informally as in (52).

(52) *Feature Licensing Condition*

In a constraint of the form IDENT[*Feat*]/**Φstr**, the following condition must be met:

Φstr must possess salient cues for the perception of *Feat*.

An examination of the contrasts listed in Beckman (1998) that are specially maintained by the psycholinguistically strong position root in the face of positional neutralization indicates that, as for the initial syllable, there are no restrictions on positional faithfulness constraints for this position. Thus, in general, there is nothing like the Feature Contrast Condition for psycholinguistically strong positions, and as a result, these positions show special licensing abilities for consonantal features as well as for vocalic features.

(53) Feature licensing by root and σ_1 (Beckman 1998)

	Root		*Initial syllable*	
V features	Height Color	(German) (Turkish)	Length Height Color Nasality	(Dhangar-Kurux) (Shona) (Turkic) (Dhangar-Kurux)
C features	Non-coronal place Affricates Clicks Xhosa) Laryngeal features [pharyngeal] Onset clusters	(German) (German) (Zulu, (Cuzco Quechua) (Arabic) (Sanskrit)	Implosives Labiovelars Secondary arctic. Clicks	(Doyayo) (Doyayo) (Shilluk) (!Xóõ)

Thus, the distinction between phonetically and psycholinguistically strong positions is relevant for positional faithfulness constraints as well as for positional augmentation constraints. The Schema/Filter model of CON can provide an account for the special restrictions on positional IDENT constraints for phonetically strong positions with the Feature Licensing Condition, a constraint filter that ensures that a phonetically strong position only licenses features with which it has a special perceptual relationship.

2.4.3 Summary

Phonetically and psycholinguistically strong positions have different substantive bases for their special status. As a consequence, constraint filters, which are the locus of substantive restrictions on phonology, are potentially sensitive to the distinction between the two classes of strong positions. Indeed, the special relationship between psycholinguistically strong positions and early-stage word recognition places restrictions on possible augmentation constraints for these positions, as modeled in the Segmental Contrast Condition (further discussion of the psycholinguistic factors formalized in this constraint filter is provided in §4.3). Another example has also been given preliminary consideration here: the special relationship between the particular phonetic salience of a phonetically strong position and the types of contrasts for which the position has **F/str** constraints can also be modeled in terms of a substantively based constraint filter.

2.5 Summary and conclusions

This chapter has developed a formal theory of **M/str** constraints. The Schema/Filter model of CON provides a way for substantive pressures to affect the universal inventory of constraints by means of constraint filters. A given constraint filter blocks the inclusion of any constraint in CON that fails to exhibit the particular substantively-based characteristic to which that filter is sensitive. Thus, the Prominence Condition rejects any **M/str** constraint whose satisfaction does not enhance perceptual prominence, and the Segmental Contrast Condition rejects any **M/Ψstr** constraint whose satisfaction affects segmental contrasts (other than those that help demarcate the left edge of the initial syllable).

It is important to note that the Schema/Filter model of CON does not automatically predict that *all* constraints in CON have some relationship to substantive factors (although such a claim certainly could be incorporated into the model). If no filter exists to reject a particular type of constraint, then even if that constraint has no substantive basis, it will not be prevented from appearing in CON.

Likewise, the approach to **M/str** constraints outlined here does not automatically predict that an **M/str** constraint exists for any phonetic characteristic that happens to be perceptually prominent. Filters do not create constraints; they merely evaluate, on the basis of some substantive factor, the constraints that are formally constructed from the set of constraint schemas and the set of basic phonological elements. Thus, if there happens to be some phonetic property that is perceptually salient, but is not part of the formal phonological system (as, e.g., a feature), then no **M/str** (or other) constraint involving that property will ever be constructed in the first place. Instead, what the theory predicts is that if there is a constraint requiring the presence of property *P*, and *P* happens to be a prominent property, then the constraint should have **M/str** counterparts.