# English Cluster Simplification and Optimality Theory: A Critique of Lexicon Optimization and Richness of the Base*

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## 1. Introduction

This paper discusses how input forms should be determined in Optimality Theory (henceforth OT; cf. Prince and Smolensky (1993) among others). In the current theory, input forms are determined by selection among various possibilities through a procedure called Lexicon Optimization. I will show that such a view on input forms is problematic in that it leads to nullification of phonology itself in the end. As an alternative, I will reorganize the architecture of grammar so that inputs are produced uniquely before the general mechanism of the theory comes into play.

In OT, grammar consists of just two functions; namely, Gen (which is the abbreviation for 'Generator') and H-Eval (or 'Harmonic-Evaluation'). The former produces a set of possible outputs for an input, and the latter selects the optimal output among them. This process is schematized as in (1):

(1) a. Gen ($In_k$) $\rightarrow$ {$Out_1$, $Out_2$,...}

b. H-Eval ($Out_i$, $1 \leq i \leq \infty$) $\rightarrow$ $Out_{real}$

(Prince and Smolensky (1993:4))

Gen can treat an input in any way: it can change or delete a segment in the input, and add a segment which is absent in the input. These manipulations of Gen produce the set of logically possible outputs for the input. These outputs are then evaluated by H-Eval, which consists of hierarchically-ranked constraints, and the one which satisfies the constraints best is selected as the optimal output.

From the schema in (1), it becomes evident that OT is made up of the following two assumptions: (i) constraints evaluate output forms, but not input forms; and (ii) Gen produces

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outputs for an input, but not inputs themselves. These are reflections of the central principle of OT, called Richness of the Base (Prince and Smolensky (1993:191)).

(2) **Richness of the Base** (Smolensky (1996:3))
The source of all systematic cross-linguistic variation is constraint reranking. In particular, the set of *inputs* to the grammars of all languages is the same. The grammatical inventories of a language are the *outputs* which emerge from the grammar when it is fed the universal set of all possible inputs.

In other words, "[t]here are no independent morpheme structure constraints on phonological inputs (Smolensky (1996:3))" in OT. There being no restriction on inputs, the input form for an output is determined through the mechanism called Lexicon Optimization, which selects the optimal input among various logically-possible inputs for an output, as we will see in detail in section 3.

In this paper, I will show that this view of input forms is problematic, and argue that inputs must be uniquely determined at the beginning. For this purpose, I will examine English cluster simplification. First, a preliminary analysis for this phenomenon is attempted under OT in section 2. In sections 3 and 4, it is shown that the current theory does not guarantee the morphological connection between *sign* and *signature*, and that it does not account for the absence of some alternations which are logically possible. I explore an alternative analysis in section 5, in which inputs are produced before Gen creates a set of possible outputs for an input. After attempting to schematize the alternative analysis into a model, I will discuss some issues which arise in my analysis in section 6. In section 7, I will conclude the paper.

## 2. An OT Analysis of English Cluster Simplification

English has several alternations in which a segment in a word-final cluster disappears in non-derived forms. The words in (3-5) are typical examples of such alternations:

(3) [m] ~ [mn]

| | |
|---|---|
| hymn | hymnal |
| damn | damnation |
| column | columnar |

(4) [m], [n] ~ [gm], [gn]

| | |
|---|---|
| paradigm | paradigmatic |
| sign | signature |

(5) [m], [ŋ] ~ [mb], [ŋg]

| | |
|---|---|
| iamb[1] | iambic |
| bomb | bombard |
| long | longer |
| strong | stronger |

The stems in (3) end with /n/, as the words in the right column suggest, but it is not pronounced if no suffix is attached, as shown in the left column. Similarly, the stem-final /g/ (and /b/ as well in (5)) does not appear in the non-derived forms in (4) and (5).[2]

It is important to note that the segments which disappear in derived forms are restricted to /n/, /g/ and /b/. In contrast to the alternation in (4), other segments are not deleted due to syllabifying the segments as nucleus, even when they are in front of the stem-final /m/; e.g. *rhythm* and *prism*. Moreover, a stem-final /d/ after a nasal does not delete although it is also a voiced stop as /b/ and /g/ are, unlike the alternations in (5); e.g. *hand*.[3] In addition, /p/ and /k/, which are voiceless counterparts of /b/ and /g/, never delete; e.g. *jump* and *bank*.

In the derivational model, these facts are analyzed by positing proper deletion rules (cf. Halle and Mohanan (1985) and Borowsky (1986) among others). In what follows, I present an analysis of these facts in the framework of OT.[4] First, let us assume the following constraints:

(6) a. **Syllabification Principles (SP)**: Segments are syllabified harmonically.

b. ***Peak/Nasal**: Nasals do not become the syllable peak.

c. **Faith(λ)**: The segment λ is present both in input and output.

**Syllabification Principles** consist of several constraints which pertain to syllabification.

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[1] As is well-known, there is an alternative pronunciation in which /b/ does appear in the non-derived form; i.e. [aiæmb]. We ignore this dialect.

[2] As is well-known, the segments in question disappear before some suffixes; e.g. *damning* [damiŋ], *signing* [sainiŋ] and *longing* [loŋiŋ]. Benua (1997, 1998) discusses the difference between these forms and those which do have stem-final segments in derived forms in OT terms. In this paper, however, I do not present a particular OT analysis of this fact since the focus of this paper is how the input forms of these words are determined.

[3] As an anonymous reader has pointed out to me, in certain environments the morpheme-final /d/ optionally disappears before "Class 2" suffixes and in compounds; e.g. *kindness* and *handbook*. I do not discuss this phenomenon in this paper, because the fact is not important in my analysis.

[4] Hammond (1997) also proposes a similar OT analysis. The difference is that my analysis makes use of more general constraints and the consistent constraint hierarchy; i.e. (8).

The Sonority Sequencing Principle, which requires "onsets to rise in sonority toward the nucleus and codas to fall in sonority from the nucleus (Kenstowicz (1994a:254))," is one of these constraints. Moreover, consonants other than sonorants cannot be the syllable peak because of one of the syllabification constraints; i.e., ***Peak/Obstruent**. The results of many other studies on syllable theory should be rethought in OT terms, but I leave this issue to future research as the definition in (6a) is sufficient for the argument made here. ***Peak/Nasal** may also be one of the **SP**s, but I refer to this constraint independently because its position in the constraint hierarchy as opposed to **SP** becomes important in my analysis. **Faith(λ)** is a constraint which requires identity between input and output with respect to a designated segment, and thus prohibits deletion and epenthesis of the segment.[5]

From the facts in (3-5), we can infer the following rankings among these constraints:

(7) a. **SP, Faith(m) » *Peak/Nas » Faith(n)**

b. **SP » *Peak/Nas » Faith(n) » Faith(g)**

c. **SP, Faith(other than *g* and *b*) » Faith(g,b)**

Because one of the underlying segments is deleted in non-derived forms, it is clear that syllabifying all the segments is impossible in these cases, which means **SP** is undominated. From the fact that some segments are deleted in the alternations, we can infer that the **Faith** constraint of the relevant segment is subordinated. As for (3), /n/, but not /m/, is deleted, and thus **Faith(m)** is ranked higher than **Faith(n)** (i.e. (7a)). Similarly, the alternations in (4) and (5) suggest that **Faith(n)** dominates **Faith(g)** (i.e. (7b)), and that **Faith(g,b)** is subordinated (i.e. (7c)). By combining all of these ranking relations, we can obtain the overall ranking:

(8) **SP, Faith » *Peak/Nas » Faith(n) » Faith(g,b)**

The top-ranked **Faith** is actually a bundle of constraints which concern the faithfulness of the segments other than /n/, /g/ and /b/; I refer to them as **Faith** for the sake of simplicity.

Now I will show that the ranking in (8) predicts correct outputs for each of the cases. First, I will analyze the alternation in (3), in which /mn/ alternates with /m/, in the tableau in (9):

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[5] **Faith** can be divided into several sub-constraints. In the present theory, it is assumed that **Max**, **Dep**, and **Ident** are the sub-constraints (cf. McCarthy and Prince (1995)). For simplification, I do not make such a distinction in **Faith** for the present discussion.

(9)

| hymn | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|
| ☞ .him. | | | | * | |
| .hin. | | *! | | | |
| .himn. | *! | | | | |
| .hi.mn̩. | | | *! | | |

Syllabifying all the segments in the input form violates the topmost constraint **SP**, as the third candidate shows, since the cluster /mn/ is not a possible coda in English. Rendering the final /n/ nucleus is also problematic, because such a syllabification violates ***Peak/Nas**; thus the fourth candidate also loses. The only option left is to delete one of the segments of the final cluster in the input, but since the **Faith** constraint for /n/ is ranked below that for /m/, deletion of /n/ yields a lesser violation and thus the first candidate is selected as the optimal output.

The alternation in (4), in which /gn/ alternates with /n/, is also analyzed in the constraint hierarchy in (8). As in the case of *hymn*, the final cluster /gn/ of *sign* cannot be saved from deletion by syllabifying it as complex coda (i.e. the third candidate in (10)) or as an independent syllable (i.e. the fourth candidate). Since **Faith(n)** is ranked higher than **Faith(g,b)**, deletion of /g/ is preferable to that of /n/; hence the first candidate wins.[6]

(10)

| sign | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|
| ☞ .sIn. | | | | | * |
| .sIg. | | | | *! | |
| .sign. | *! | | | | |
| .si.gn̩. | | | *! | | |

Unlike the words in (3) and (4), words such as *rhythm* and *prism* do not undergo deletion to avoid illegal codas: instead, the final /m/ is syllabified as nucleus to constitute an independent syllable. This fact is also explained in this analysis as shown in tableau (11):

6 In this case, a constraint like **Faith-$\mu$**, which requires the identity of syllable weight, is necessary to account for the fact that the vowel is lengthened, as is indicated by the capital letter in the tableau. However, I set aside this issue here because it is important in this paper.

(11)

| rhythm | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|
| .rim. | | *! | | | |
| .rið. | | *! | | | |
| .riðm. | *! | | | | |
| ☞ .ri.ðm̩. | | | * | | |

Deletion of /ð/ and that of /m/ both commit a fatal violation of **Faith**, and thus the first and the second candidates in (11) lose. ***Peak/Nas** being ranked below **Faith**, the fourth candidate, in which /m/ is syllabified as nucleus, wins over the third candidate, which violates the top-ranked constraint **SP** by syllabifying /ðm/ as coda.[7]

Finally, we will consider the alternation in (5), in which /mb/ alternates with /m/ and /ŋg/ with /ŋ/. It is important to note, as I have mentioned, that /nd/ does not alternate with /n/ although /d/ is also a voiced stop. This is because, I assume, some constraints in **SP** prohibit /mb/ and /ŋg/ as codas, but not /nd/.[8] Hence, the third candidate in (12) loses. Just as in the cases above, syllabifying /g/ as nucleus is fatal, as shown in the fourth row (recall that ***Peak/Obstruent** is included in **SP**). Because of the difference in the position of the **Faith** constraint in the hierarchy, the first candidate, which deletes /g/, wins just as in the case of (10).[9]

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7 As for words such as *button*, which have syllabic /n/ after obstruents, I assume that these words contain a vowel in front of the /n/, as the spelling suggests. It must be a phonetic (or postlexical) phenomenon that the vowel is deleted and the /n/ becomes syllabic; otherwise it is impossible to explain why the /g/ in *sign* is deleted while the /d/ in *sudden* is syllabified as the onset of the following syllabic /n/. Moreover, alternations such as *person* [pə́ɹsn̩]/*personify* [pəɹsɑ́nəfai] and *metal* [mɛ́tl̩]/*metallic* [mətǽlɪk] suggest that there are underlying vowels before the syllabic segments, which get stressed in the derived words.

8 Hammond (1997) analyzes this fact in the same way. He considers that "the sequence nasal + [voiced stop] is too similar in sonority for codas (p.355)." However, as he mentions, it remains to be solved why this sonority constraint does not apply to /nd/. This may have something to do with the underspecified status of coronals, but I do not have a clear answer here.

9 We need a constraint to account for the place assimilation found in [ŋ], which is underlyingly /n/, somewhere in the hierarchy. However, I ignore this constraint here since it is not crucial to my argument.

(12)

| long | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|
| ☞ .loŋ. | | | | | * |
| .log. | | | | *! | |
| .loŋg. | *! | | | | |
| .lo.ŋg. | *! | | | | |

On the other hand, sequences such as /nd/ and /mp/ are not prohibited as codas, and thus no deletion applies to the words which end with such clusters:

(13)

| hand | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|
| .han. | | *! | | | |
| .had. | | | | *! | |
| ☞ .hand. | | | | | |
| .ha.nḍ. | *! | | | | |

As we have seen above, the ranking in (8) correctly predicts the actual outputs for all the cases. However, some crucial problems arise in the current view of grammar in OT, which I summarized in the previous section. In the following two sections, I will point out the problems.

## 3. Lexicon Optimization and Its Problem

Before I begin the discussion, let us first review the process of Lexicon Optimization, which is the only mechanism in current OT to fix the form of the input. Recall that OT does not have any restriction on input forms, and thus any form that is logically possible can be the input for an output (recall the assumption of Richness of the Base in (2)). By means of Lexicon Optimization, whose definition is given below, Prince and Smolensky (1993) attempt to fix the form of an input uniquely:[10]

(14) Lexicon Optimization (Prince and Smolensky (1993:192))

Suppose that several different inputs $I_1$, $I_2$, ..., $I_n$ when parsed by a grammar

[10] Inkelas (1997) gives a different definition of Lexicon Optimization. The difference is that she allows outputs to be underspecified with some features, and thus the underspecified segment of the output form can appear as various phones on the surface according to the environment. This difference is not important in my argument here.

G lead to corresponding outputs $O_1, O_2, \ldots, O_n$, all of which are realized as the same phonetic form $\phi$ — these inputs are all *phonetically equivalent* with respect to G. Now one of these outputs must be the most harmonic, by virtue of incurring the least significant violation marks: suppose this optimal one is labelled $O_k$. Then the learner should choose, as the underlying form for $\phi$, the input $I_k$.

In other words, Lexicon Optimization chooses the input which incurs the least serious violation among the inputs which are logically possible for an output. To illustrate how this method works, let us consider the Japanese word *tombo* 'dragonfly' as an example, which is discussed by Itô, Mester and Padgett (1995).

(15) "tableau des tableaux" (Itô, Mester and Padgett (1995:593))

| Input | Output | License | NasVoi | Faith |
|---|---|---|---|---|
| a. /tompo/ | t o m b o<br>\ /<br>v | | | *!* |
| b. /tompo/<br>\|<br>v | t o m b o<br>\| /<br>v | | | *! |
| c. /tombo/<br>\|<br>v | t o m b o<br>\ \|<br>v | | | *! |
| d. ☞ /tombo/<br>V<br>v | t o m b o<br>\/<br>v | | | |
| e. /tombo/<br>\|\|<br>v v | t o m b o<br>\| / ≠<br>v v | | | *!* |

The output *tombo* can be attained from all of the inputs in (15a-e) by affecting the input in some way (the symbol 'v' in the inputs and the outputs indicates the presence of the feature [voice]). None of the outputs violates the constraints **License**, which requires that all features be licensed, and **NasVoi**, which requires that nasals be voiced, but **Faith** is violated by the output of some inputs by inserting, deleting, or spreading the [voice] feature. By virtue of Lexicon Optimization, the input form in (15d) is selected as the input for *tombo*, since it incurs no violation of **Faith**, which is the fewest among the inputs.

This way of determining the input form, however, raises a serious problem for phonological theory; that is, the identity of an input cannot be guaranteed. In the case of English cluster simplification, for example, Lexicon Optimization cannot guarantee the presence of /g/ in the input form of /sign/. In what follows, I will illustrate this point. First, consider the tableau below, which evaluates the input form /sign/:

(16) (= (10))

| sign | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|
| ☞ .sIn. | | | | | * |
| .sIg. | | | | *! | |
| .sign. | *! | | | | |
| .si.gn̩. | | | *! | | |

As is discussed in the previous section, we can correctly predict the actual output *sIn* [sain]. Next, let us consider the case in which the input form of *sIn* is also /sIn/. This is possible in current OT, since there is no restriction on the input form because of Richness of the Base.

(17)

| sIn | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|
| ☞ .sIn. | | | | | |
| .sIg. | | | | *! | * |
| .sign. | *! | | | | * |
| .si.gn̩. | | | *! | | * |

Again, the correct form *sIn* is selected as the optimal output in this case. The first candidate in (17) is provided with entirely proper syllabification, and incurs no **Faith** violation without any deletion or epenthesis, and is thus optimal among the candidates. Now, we will determine which of the forms in (16) and (17) is the optimal input by means of Lexicon Optimization.

(18)

| input | output | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|---|
| sign | sIn | | | | | *! |
| ☞ sIn | sIn | | | | | |

When we compare the two forms, we can easily conclude that the form /sIn/ is more optimal as the input because it incurs no violation; /sign/ is less optimal in that it undergoes the deletion of /g/.

This conclusion raises a serious problem when we consider the connection between *sign* and *signature*, that is, between a stem and its derived word. Note that the input form of *signature* would include the segment /g/, otherwise there is no motivation for the epenthesis of this segment. On the other hand, the input form of *sign*, which is the stem of *signature*, does not contain the segment according to Lexicon Optimization, as we have seen. If that is the case, how can these two words be related? It would be impossible to say that *signature* is morphologically derived from *sign*, because these two words have different input forms. In other words, they would be considered independent words and would have no more relation than *horse* has with *whale*.

**Output-Output Identity** constraints (cf. Benua (1995, 1997, 1998), Kenstowicz (1994b), Itô and Mester (1997), etc.), which require identity between different output forms, do not solve this problem. Suppose there is a constraint which requires *sign* to be identical with *signature* (I will temporarily call this constraint **OO-I**). Crucially, the correct output violates this constraint anyway, because the output [sain] does not contain the segment /g/, which *signature* does. Wherever it is ranked in the constraint hierarchy, Lexicon Optimization selects /sIn/ for the input of [sain].

(19)

| input | output | SP | Faith | *Peak/Nas | OO-I | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|---|---|
| sign | sIn | | | | * | | *! |
| ☞ sIn | sIn | | | | * | | |

cf. signature

This is the most serious problem that Lexicon Optimization inherently has. Note that when a word undergoes a phonological change, the word would always violate some **Faith** constraint or **OO-Identity** constraint, because the word is different from the original form in some respect. On the other hand, if inputs are not restricted in any way, there is always an input which has the same shape as the output. The optimal output of this input of course marks the least number of violations among the inputs that are logically possible: this input incurs no violation of **Faith** and **OO-Identity** constraint, which the optimal output of any other inputs inevitably violates, and is on a par with other inputs with respect to the other phonological constraints. Thus, the input which is identical to the output form is always selected as the optimal input through Lexicon Optimization.

Consequently, forms which were once considered to have undergone morphological and phonological processes are now regarded as being as they are from the beginning; in the case of *sign* and *signature*, the latter is not considered to have derived from the former through suffixation and the former is not considered to have undergone the process of cluster simplification, because the two words are distinct in the input form. The conclusion is that Lexicon Optimization makes it impossible to posit the same stem for a stem and its morphologically-derived word, and we have no phonological basis to relate them to each other. Moreover, if every word is distinct, there remains no phonology in the long run: every word is just registered as it is. Is this an adequate consequence for any phonological theory, when it throws away all the fruit that previous studies have born so far?

Actually, Prince and Smolensky (1993) suggest a solution to this kind of problem by introducing the following constraint into grammar (p.196):

(20) ***Spec**: Underlying materials must be absent.

When this constraint is ranked higher than **Faith**, an analysis containing less morphemes is more optimal than, and thus wins over, the one which has several allomorphs for a morpheme. In the relevant case, containing two allomorphs *sIn* (for *sign*) and *sign* (for *sign-ature*) is worse than having just *sign* for both words, and thus the input of the stem is uniquely determined by this ranking.[11] This analysis, however, is improper in the following two respects. First, the general mechanism of current OT, which we have seen in (1), does not have room to place the relevant constraint in the grammar. Putting it into the constraint hierarchy in (8) does not produce the intended effect, because evaluation is carried out individually for an input: it is impossible to evaluate several inputs in a tableau at the same time. Moreover, although it is assumed in OT that constraints evaluate only output forms, ***Spec** evaluates input forms directly, which is impossible in the general mechanism in (1).[12] Therefore, we can conclude that it is impossible to guarantee a unique input for the stem in question by means of the current architecture of grammar in OT. It seems to be necessary to reorganize the architecture, so that inputs are determined uniquely and restricted directly by constraints.[13]

## 4. The Absence of Possible Alternations

Another problem which current OT raises is that it cannot appropriately account for the absence of some possible alternations in English. Because we have the alternation *sign*

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[11] I am grateful to an anonymous reader for pointing out this possibility to me.

[12] This problem also arises in another possible solution for the issue in question, which has been pointed out to me by Mafuyu Kitahara (p.c.). He has suggested that a constraint like **Input-Input Correspondence** will eliminate the problem of unrestricted inputs, but such a constraint is problematic in that it evaluates input forms, not output forms.

[13] Other discussions against Lexicon Optimization are given in Zamma (1997a, 1998).

/*signature*, it is natural to expect an alternation such as **tidn/tidnic* in the current theory, which does not actually exist.[14] In current OT in which the form of the input is not restricted at all, the form **tidn* is entirely possible as an input for a stem. The constraint hierarchy in (8) predicts that this stem would undergo deletion when it appears without a suffix, and that the whole sequence appears on the surface when the stem is followed by a vowel-initial suffix:

(21)

a.

| tidn | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|
| .tIn. | | *! | | | |
| ☞ .tId. | | | | * | |
| .tidn. | *! | | | | |
| .ti.dn̩. | | | *! | | |

b.

| tidn + -ic | SP | Faith | *Peak/Nas | Faith(n) | Faith(g,b) |
|---|---|---|---|---|---|
| .tI.nic. | | *! | | | |
| .tI.dic. | | | | *! | |
| ☞ .tid.nic. | | | | | |
| .ti.dn̩.ic. | | | *! | | |

The difference is that the non-derived form of **tidn* would appear with the stem-final /n/ deleted, as the second candidate in tableau (21a) shows, while /g/ is deleted in the non-derived form of *sign*, which is not stem-final (cf. (10)). This comes from the fact that the **Faith** constraint of /g/ is ranked in the lower place in the hierarchy than that of /n/, which predicts the deletion of /g/, while the **Faith** constraint of /d/ (which is contained in the general **Faith**) is ranked higher than that of /n/, which predicts the deletion of /n/. As in the case of the stem /sign/, the suffixed form of the stem */tidn/ would not undergo any deletion because each of the segments in the final sequence is syllabified into different syllables without causing any violation, as shown in (21b).

Of course, such an alternation does not actually exist in English. In current OT, however, this alternation is predicted because the input is never restricted and an input always

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14 An anonymous reader has pointed out to me that it may be an accidental gap that we do not have stems like **tidn*. However, the fact that stem-final nasal is allowed only after /g/ suggests that there is a strong restriction on stem formation, as I will discuss in the next section.

has an optimal output in the evaluation. Lexicon Optimization, which is the only mechanism in current OT operating in the determination of input forms, does not account for such absence of the alternation: Lexicon Optimization just selects a proper input among various possibilities for an output, but does not exclude a particular input. Again, a problem arises from the stipulation that constraints have influence only on output evaluation, but not on input production.

A possible way to solve the problem in question within the framework of the current theory would be like this. First, let us assume the following constraint in English as a first approximation:

(22) **Morpheme Structure Constraint (MSC)**:

Morphemes can end with /gm/, but not with /dn/.

The definition in (22) is, of course, only temporary, because there are much more sequences that are logically possible but are prohibited in English in stem-final position. The complete constraint might consist of several sub-constraints, which prohibit such illegal sequences. This assumption imposes an enormous cost on grammar in that it dramatically increases the number of constraints, but it is theoretically possible at least.

Now, let us suppose that the **MSC** is top-ranked in the constraint hierarchy. As for the non-derived form */tidn/, the new ranking will defeat candidates which end with /dn/, thus no words can end with the sequence. On the other hand, the derived form with a vowel-initial suffix is also prohibited by the top-ranked **MSC**, because this constraint always prohibits the sequence to arise, irrespective of whether it appears without suffixes or in front of a vowel-initial suffix. Hence, there are no alternations like **tidn/tidnic*.[15]

However, the **MSC** presented above is strange in nature, as ***Spec** in the previous section is: while constraints in OT is meant to evaluate the forms of outputs, the role of the **MSC** is to exclude impossible forms as the stem in English. In other words, the **MSC** in effect prohibits the form with the sequence mentioned in the constraint to occur as an input of a stem. As I have argued in the previous section, such a restriction on inputs by a constraint is

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[15] Hammond (1997) presents a similar analysis, proposing that the pairing of form and meaning is achieved through constraints such as below:

(i) CAT = kæt

The constraint above requires that the meaning CAT be assigned to the sequence /kæt/. Unfortunately, however, his analysis of the absence of the alternation does not support his main claim of the pairing of form and meaning through constraints, when he has to assume a constraint on morpheme structure (cf. fn.16): by means of morpheme structure constraints, the current theory can account for the absence without recourse to such a revision of input forms in general, albeit the unnaturalness of the constraint as I discuss here. Moreover, his analysis raises another question why meanings are paired only with forms that are legal in a given language.

totally impossible in the current architecture of OT. In order for the MSC to work well, that is, to exclude the impossible sequence in the stem, we have to reorganize the architecture of the theory so that such a restriction is imposed directly on the form of inputs.

## 5. Alternative Analysis

The discussion so far has proved that the present view of OT on the input form is problematic, because Richness of the Base together with Lexicon Optimization cannot guarantee the relation between a stem and its morphologically-derived word. Moreover, it is impossible to account for the absence of some possible alternations in the current theory. The discussion presented above strongly suggests that some constraints which refer to input forms are necessary even in OT. On the basis of these observations, I will explore an alternative analysis which includes some constraints that take effect at the stage of input production, abandoning the general principle of Richness of the Base.

Now, let us reconsider the issue of cluster simplification in English. As I have argued in the previous sections, what I have to do in my analysis is the following: (i) to guarantee the identity of a stem and maintain the relation between non-derived and derived words; and (ii) to exclude the impossible stem-final sequences in English. The first task is achieved when I assume that inputs are uniquely *produced*, not *selected*, before the general mechanism of OT comes into play. That is, I abandon the principle of Richness of the Base, by which inputs are assumed to be unrestricted. Given that the stem is defined as it is at the beginning, it is a matter of course that a stem and its derived word are connected and have identity between them.

As for the second issue, I assume that input forms are not created freely, but are restricted to a certain degree. Because of this restriction, I assume, only a limited range of sequences is created in a language. For the case at hand, let us assume the following MSC in English, which is a revised version of (22):

(23) MSC (revised):

Nasals can be attached to /g/ morpheme-finally.

This constraint satisfactorily allows stems such as *sign* and *paradigm*, but disallows a stem like **tidn*.[16] Note that it is only the segment /g/ that can be followed by nasals stem-finally: there

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[16] Hammond (1997) proposes a similar constraint, but his is not satisfactory because his formulation of the constraint cannot exclude morpheme-final /dn/, for example.

are no stem-final sequences such as /pm/, /tn/, etc.[17] The formulation of the **MSC** might be changed to accommodate clusters which are not treated in this paper, or restated in more general terms, but it is sufficient now for us to say that there is a constraint like (23).

As is often studied in the literature, particularly by Cairns (1988) among others, there are much more phonotactic constraints in English.[18] Morphemes are created by arranging the segments so that they obey such phonotactic constraints at the stage of input production. The stems *damn*, *bomb* and *sign* are created with the segments which are deleted in non-derived forms, as the spelling shows. The stem **tidn* cannot be produced, because such a sequence is not allowed by the **MSC**. Now I have accomplished my second task I mentioned above: because a stem like **tidn* is not created, such an alternation as **tIn/tidnic* does not exist. After the identification of each input, the general mechanism of OT applies and the phenomenon known as cluster simplification results, as we have observed in section 2.

The conclusion we have drawn here is rather a simple one: inputs are uniquely defined before the process of evaluation applies to them, which is similar to the establishment of underlying forms in traditional derivational theories. Only by doing so, though, can we identify the input form as it is, and account for the absence of some possible alternations. Moreover, this approach has a great advantage over the standard version of OT, which is equipped with the principle of Richness of the Base. The advantage is that we can dispense with the procedure of Lexicon Optimization from grammar. In what follows, I will argue how advantageous this abolition is.

Without Lexicon Optimization, we can dramatically reduce the cost of evaluation for determining proper inputs. Note that on the assumption that inputs are unrestricted, an enormous number of possible inputs must be evaluated for an output. Since the function Gen can treat the input in any way, there are a great number of possible input forms for one output [kæt]; e.g., /kɔt/, /kɛt/, /kʌt/, /gæt/, /kæd/, etc. Even completely different inputs such as /dɒg/, /pɪg/, /bɪl klɪntən/ are possible for this output.

Moreover, if it is the case that some of the input segments are underspecified, as is actually assumed in some studies in OT, then we have to consider much more possibilities. For example, suppose that the segment /k/ consists of the following nine features; i.e.

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[17] As for words like *button*, which has syllabic /n/ on the surface, I assume that there is an underlying vowel before the /n/. See footnote 7 above.

[18] Cairns's system does not predict *rhythm* and *prism*, though, while it allows *bomb* and *hymn*. A certain amount of refinement seems to be necessary.

[+consonantal], [-continuant], [-sonorant], [+back], [+high], [-anterior], [-coronal], [-strident], [-voice]. Then, there are logically 9! = 362,880 possibilities for a representation of /k/, because the logical combination of specified features among them is entirely free. Also, the vowel /æ/ consists of four features (i.e. [-high], [+low], [-back], [-round]), and /t/ of nine features (i.e. [+consonantal], [-continuant], [-sonorant], [-back], [-high], [+coronal], [+anterior], [-strident], [-voice]), thus there are 4! (= 24) and 9! (= 362,880) possibilities for their representations respectively. Then, there are logically 368,220 x 24 x 368,220 = 3,254,063,241,600 possibilities for a representation of /kæt/. Crucially, these are possibilities only for the case in which the input form is identical to the output [kæt]. Since an output can be generated from any input form by Gen, as I have mentioned above, the number of possible representations for an input becomes enormous and completely uncountable.

As is demonstrated in Zamma (1997a), an input form is determined only after evaluating all of these possibilities: the one whose output incurs the least significant violation is selected as the optimal input. Furthermore, since Gen produces an infinite number of outputs for an input, determining the optimal output is highly costly itself. Hence, the cost of evaluation in the process of Lexicon Optimization is incredibly high, under the assumption of Richness of the Base.

When we identify a single representation for an input, on the other hand, the cost is dramatically reduced. We do not have to consider inputs such as /kɔt/, /kɛt/ and the like for the output [kæt]: we just only have to consider the input /kæt/. Even when we underspecify some of the features of the input, we can determine which feature(s) to underspecify, perhaps from phonological phenomena of the language. Thus we do not have to consider 3,254,063,241,599 or more cases of inputs under the present analysis. It is apparent that my analysis is much more economical than, and thus preferable to, the current one.

## 6. Modeling

Before I close the discussion on input forms in OT, it seems to be desirable to schematize my analysis in a model, in order to show how my proposal compromise with, or is incorporated into, the standard model of OT we have seen in (1). As I have clarified, it is necessary in OT that input forms are determined before Gen produces output candidates. Moreover, restrictions should be put on input forms so that some stems which are logically possible may not appear. From these observations, it is reasonable to assume that there is a distinct stage at which inputs are identified as they are and regulated by some constraints. So, I can schematize the model as below, following Zamma (1997a:16).

(24) input production

↓

output selection (Gen + H-Eval)

Before the stage at which the general mechanism of OT (i.e. Gen + H-Eval) derives the optimal output, I assume, the input form is produced uniquely at a distinct stage. The **MSC's**, the constraints on the form of the input, come into effect at this stage.

At the next stage, the output form for an input is selected through Gen and H-Eval. A set of candidates is created by Gen for an input, and the candidates are evaluated in the constraint hierarchy. In this evaluation, a candidate which is different in form from the input can be selected as optimal, when some **Faith** constraints are ranked lower than relevant phonological constraints. This is the case where we observe phonological alternation in a given language. For the cases we are dealing with, the non-derived forms *damn*, *bomb*, and *sign* appear with some segment underparsed; i.e. [dæm], [bɑm] and [sain]. When a vowel-initial suffix is attached, on the other hand, the stem-final segments are parsed faithfully without undergoing deletion; thus *damnation*, *bombard*, and *signature*.

Furthermore, it seems to be possible to posit another stage after the one for output selection; that is, the stage of phonetic realization. Note that there has been a consensus among researchers that there is a distinction between phonology and phonetics, as is suggested by the postulation of distinct "postlexical" level in Lexical Phonology (cf. Kiparsky (1982), etc.). If it is the case that we should maintain this traditional assumption on the distinction, we can expand the model in (24) into the following model, as is suggested by Zamma (1997a:17):

(25) input production

↓

output selection (Gen + H-Eval)

↓

phonetic realization

Of course, it is a delicate problem where to draw a line between phonology and phonetics. Moreover, it is not still clear how OT deals with phenomena once analyzed as "postlexical." Note, however, that some researchers analyze such "postlexical" phenomena in OT terms; for example, McCarthy and Prince (1993:125-126) discuss phrasal syllabification, Cho (1995) English flapping, Itô and Mester (1997) and Itô (1997) allophonic *g*/*ŋ* alternation in Japanese, and so on. Moreover, Hayes (1996), Kirchner (1996), and Steriade (1996) analyze phenomena that were once considered to belong to phonetics (although they aim at getting rid of the distinction between phonology and phonetics). These studies suggest that "phonetic" phenomena can be analyzed in the framework of OT, even when we make a distinction between phonology and phonetics.

As is pointed out by Zamma (1997a), such a threefold process of sound production looks similar to the model of Harmonic Phonology, which is advocated mainly by Goldsmith (1990, 1993). The identification of the three "levels" in Harmonic Phonology is given below:

(26) M-level: a morphophonemic level; the level at which morphemes are phonologically specified.

W-level: the level at which expressions are structured into well-formed syllables and well-formed words, but with a minimum of redundant phonological information.

P-level: a level of broad phonetic description that is the interface with the peripheral articulatory and acoustic devices.

(Goldsmith (1993:32))

Goldsmith and the proponents of his approach assume that phonological rules apply within each level or between the levels. As we do not employ "rules" to describe phonological phenomena, following the central idea of OT, it is apparent that the theoretical apparatus between the models in (25) and (26) are different. Note, however, that the spirits behind the two models are the same: both models regard inputs as being uniquely identified and restricted by some restrictions in a given language (i.e. at the stage of input production or M-level) before some phonological process apply to them (i.e. at the stage of output selection or W-level), and assume that there is a distinction between phonology (i.e. phenomena which occur at the stage of output selection or W-level) and phonetics (i.e. those which occur at the stage of phonetic implementation or P-level).[19]

Note that the models presented above do not contradict the central claim of OT: as McCarthy (1997:247) notes, "[...] OT is about how grammars are defined by constraint hierarchies," and thus the theory is not damaged if some implementational aspects are changed. Actually, the principal advocators of this theory do not deny the possibility of multi-stratal lexicon (cf. McCarthy & Prince (1995:367), McCarthy (1997:248)). However, I am not sure

[19] Booij (1997) also proposes a threefold model of phonology in OT, arguing that his cyclic, post-cyclic and postlexical levels correspond to the three levels of Harmonic Phonology. However, because Goldsmith never assumes cyclicity in M-level, the model of Harmonic Phonology is much closer to my model.

whether it is adequate to use the term "levels" to represent the distinctions above, because the term is suggestive of derivational manipulation of rule-based theories. As I have just mentioned, what is expressed in the model in (24) (or (25)) is that inputs are determined before they undergo phonological alternations (and that there is a distinction between phonology and phonetics in (25)), and thus it is not implied in the models that there are derivational processes between the stages.

It remains to be surveyed how each of the stages is organized. The architecture of the stage of input production, for example, is not clear; what I have clarified so far is just that the stage consists of constraints on morpheme structure and phonotactics, such as (23).[20] Moreover, the nature of the input constraints and the relation between them must be clarified. In what follows, I will consider these issues and present a possible analysis.

As for the relation among the input constraints, constraint hierarchy, the central mechanism of OT, would be suitable to express it. For example, I have argued in the previous section that the **MSC** in (23) produces the stem *sign*. This sequence, however, is observed only morpheme-finally, but not elsewhere. This means that the sequence which is not created by phonotactic constraints alone is allowed by the **MSC**. In other words, the **MSC** takes precedence over phonotactic constraints. This would be a reflection of the constraint hierarchy **MSC** » Phonotactic Constraints.

When we pay attention to the nature of the input constraints, we notice that there is the possibility that the above ranking is derived from a general metaconstraint. Note that the **MSC** in (23) does not seem to have a generality among languages, and thus that it is natural to regard it as a constraint specific to English.[21] If so, we can easily paraphrase the ranking **MSC** » Phonotactic Constraints into general terms: language-specific constraints take precedence over general constraints at the stage of input production. Clearly, this is a reflection of Pāṇini's Theorem or Elsewhere Condition (cf. Kiparsky (1973)).

Returning to the issue of the architecture, there is another example which shows that constraint hierarchy is a proper mechanism to express the architecture of the stage of input production. Note that it is natural to assume that the phonemic inventory is stored at this stage, because inputs are identified by arranging the phonemes of a given language. Recall now that

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20 Moreover, we should await future investigations for the **MSC**'s in other languages; at present, those for Catalan are studied by Zamma (1997b), and for Tamil by Kaun (1998).

21 Kaun (1998) also argues that input constraints in Tamil are language-specific, although she assumes that the constraints are unranked.

there are some studies which try to express the inventory by means of constraint hierarchy. For example, Padgett (1997) argues that the vowel inventory of a language is defined by constraint hierarchy, and Prince and Smolensky (1993:Chapter 8) define the sonority hierarchy as the consequence of constraint interaction. These studies suggest the possibility I have just mentioned.

Finally, let us briefly discuss the nature of the stage of phonetic realization, which is not the main focus of the present paper. As is mentioned above, some of the recent studies such as Hayes (1996), Kirchner (1996), Steriade (1996), etc., try to analyze phonetic phenomena in OT terms (although they are heading for the direction opposite to my approach; that is, they try to get rid of the distinction between phonology and phonetics). In addition to this, some studies treat phenomena once analyzed as postlexical in OT (cf. McCarthy and Prince (1993), Cho (1995), Itô and Mester (1997), Itô (1997), etc.). These facts suggest that this stage also consists of constraint hierarchy.

The investigation in the framework of OT on the nature of the stages I have proposed has just begun, and it is not yet clear what is the most proper way to treat them in the theory. To draw a complete picture of each stage, we should await future research.

## 7. Concluding Remarks

We have seen that the prevalent view of OT on inputs, namely Richness of the Base, causes serious problems; that is, (i) morphemes cannot guarantee their identity between the base and the derived word, and (ii) the absence of possible alternations cannot be explained. These problems are easily solved by assuming that each of the inputs is uniquely produced before it enters the stage at which Gen and H-Eval, the familiar OT functions, come into effect. Since the input is restricted so that a stem is uniquely determined, the identity of the stem between words is guaranteed. By positing constraints on morpheme production, the absence of some possible alternations is easily accounted for. Phonological alternations, which dozens of previous studies in OT have analyzed, are considered to take place at the subsequent stage of output selection, thus the products of the previous studies are never spoiled. What is more, the framework presented here greatly lessens the burden on evaluation: since an input is provided with a single form, it is no longer necessary to evaluate other possible forms of the input. It is clear that my approach is more advantageous than the current one.

Several issues may arise in my analysis, because the investigation in the new framework has just begun. I briefly discussed in the last section what is the nature of the input constraints and how each level is designed, and suggested a possibility that the input constraints are language-specific and thus take precedence over other general constraints because of Pāṇini's Theorem, which suggests that the stage of input production also comprises of constraint hierarchy. Previous studies seem to suggest that constraint interaction also defines the stage of phonetic implementation, but we have to await future research to get the conviction that we are on the right track.

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