# On the Relation between Phonetics and Phonology\*

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Chang, Woohyeok. 2012. On the Relation between Phonetics and Phonology. Linguistic Research 29(1), 127-156. This study examines the nature of the relationship between phonology and phonetics and advocates a modular view in which there is a principled mapping between phonological representations and phonetic expressions. In particular, this modular view is advocated by Laboratory Phonology that can be characterized by two beliefs. First, it is believed that there should be a division between phonetics and phonology. Second, there should be a considerable interconnection between them. Contrary to this modular view, other approaches are somewhat radical in that abstract phonological features are not associated with phonetic facts and that phonetics and phonology are integrated into a single module which is all phonetic. In favor of the modular theory, I propose a principle about phonology-phonetics interface: unmarked items display a wider range of phonetic realization but cannot be realized in a more marked way than their marked counterparts. One representative evidence would be that the higher pitch value of a tone compared with other tones has to be a phonological high tone rather than a low tone. Further discussions about phonology-phonetics interface are done with regard to speech perception and production. It is shown that perception and production data are valid when they are used as phonetic evidence to resolve phonological controversies. On the other hand, the P-map hypothesis seems invalid when dealing with some cases where speech production and perception do not match. (Dankook University)

**Keywords** relation between phonetics and phonology, abstract phonology, laboratory phonology, unified model, phonology-phonetics interface, P-map

# 1. Introduction

Throughout the history of linguistics, one of the intractable problems has been to define the proper relation between phonology and phonetics. With regard to this issue, there are at least three clear possible perspectives. First, there is no interface between phonetics and phonology with the fully autonomous nature of them

<sup>\*</sup> The present research was conducted by the research fund of Dankook University in 2010. I would like to thank the anonymous reviewers of this journal for their helpful comments.

(Hjelmslev 1953, Fudge 1967, Foley 1977 among others). This can be characterized as an abstract view of phonology because somewhat concrete phonetic properties are not employed to characterize abstract phonological components. Second, phonology and phonetics are unified, whereby phonetics and phonology are parallel with direct relations between them (Steriade 1993, 1997, Flemming 1995, 2001, Kirchner 1997, 1998, Hayes 1997, etc.). The basic idea of this position is that the properties of phonology and phonetics should be equally interpreted in a unified (integrated) single module rather than two separate modules (phonological and phonetic modules). The last view is somewhat in the middle of the above two radical positions. That is, there is a separation between phonology and phonetics; however, they are strongly connected with each other. In fact, this view is well represented by Laboratory Phonology (Keating 1988, 1994, Anderson 1981, Pierrehumbert 1980, etc.) since it emphasizes the interaction or interface of phonetics and phonology.

In this paper, I aim to show that the non-radical view ("modular theory") is better than the other two radical views, such as the fully abstract view and the "integrated theory." According to the abstract view, phonological and phonetic representations are independent from each other, which induces arbitrary mapping between them. This can cause some problems in characterizing phonological features proposed by Lombardi (1991). The features that she employed in her study are so abstract that they cannot be properly defined, which results in arbitrary features. In the case of the integrated theory, phonetic details are incorporated in phonological representations. Accordingly, the number values that are measured and computed are present in phonological analysis. This is, in fact, different from our mental process because we do not store those numbers in our memories. In other words, this unified view fails to explain why speech sounds are perceived categorically rather than continuously. In favor of the modular theory, I propose a principle about phonology-phonetics interface: if we have two phonological representations, A and B, and A is more marked than B, then it should not be the case that the phonetic expression of B is more marked than the phonetic expression of A.

The paper is organized as follows. In chapter 2, I introduce three different views on the relationship between phonetics and phonology. Chapter 3 then provides some evidence that supports for the non-radical view on the relation between phonetics and phonology, pointing out inherent problems of the other two radical views on it. In favor of the non-radical position, a principle about phonology-phonetics interface is also proposed in this chapter. At the end of the chapter, some examples of tone reversal are presented, and tone reversal is proved not to be a counterexample to the principled connection between phonology and phonetics. In chapter 4, some further discussions are provided about phonology-phonetics interface. It is demonstrated that phonetic evidence is more valid than others when it is utilized to resolve phonological controversies. The role of speech perception and production in phonology is also dealt with to examine the relationship between phonetics and phonology. Finally, chapter 5 serves a summary of this paper.

# 2. The Relationship between Phonetics and Phonology

The relationship between phonetics and phonology has long been debated because both phonetics and phonology share a common interest in the sounds of all human languages, and because phonetics and phonology are often differentiated in terms of concrete phonetic scales vs. abstract phonological features. One conception of the most crucial difference of features between phonology and phonetics is found in the values of phonological and phonetic features. It is generally assumed that in phonology the values of features are unary or binary whereas phonetic features are typically expressed as more than two values ("n-ary," see Postal 1968) or even continuous. With regard to the relationship between phonetics and phonology, there have been largely three different positions. These are: (i) a clear separation with an arbitrary mapping relation between them (i.e., phonetics = phonology); (ii) parallels with direct relations between them (i.e., phonetics = phonology).

# 2.1 Abstract View of Phonology

One a priori possibility would be a clear separation between the two categories with arbitrary laws of interface between them. This would be a fully abstract view in the sense that under this view only phonology is conceived as properly part of grammar due to its formal, cognitive, and abstract nature. Conversely, phonetics fails to be assigned as part of the grammar in this view, it being relegated to bio-physics. Given the distinct properties between phonology and phonetics under this view, there is an arbitrary mapping from phonology to phonetics. The basic assumption is that phonetic components vary from one language to another. That phonology and phonetics are regarded as entirely autonomous is of particular importance in this radical abstract view. As an example of a proponent of such a view, consider Foley (1977), quoted in (1):

(1) "In concluding this discussion of the phonological parameters and their phonetic manifestation, it should be stressed that it is not so much the particular parameters discussed here (which will require change and revision), but rather the concept of establishing phonological elements independent of phonetic definition which is important. Only when phonology frees itself from phonetic reductionism will it attain scientific status." (p. 52)

First of all, the first radical view (phonetics  $\neq$  phonology), as pointed out by Ohala (1997), has its origins in "structuralism, taught initially by Ferdinand de Saussure (1857-1913) and Jan Baudouin de Courtenay (1845-1929) but fully developed in phonology by the Prague School" (p. 680). At the core of the Prague School is a commitment to a downgraded perceptive on phonetics based on the assumption that phonetics should be occasionally reduced to a mere ancillary role. Endorsing this perspective, Hjelmslev (1953) presented a formal approach to linguistics, suggesting that linguistics should not be compatible with non-linguistic elements, such as "physical, physiological, psychological, logical, sociological" phenomena. Subsequently, Foley (1977) and Fudge (1967) further elaborated the division between phonology and phonetics. In their view, phonological items are represented as abstract and arbitrary features devoid of any direct phonetic information. Foley (1977) particularly emphasizes that phonological elements ought to be identified in terms of the rules that they are subject to rather than their acoustic or articulatory properties, as quoted in (2):

(2) "As for example, the elements of a psychological theory must be established without reduction to neurology or physiology, so too the elements of a phonological theory must be established by consideration of phonological processes, without reduction to the phonetic characteristics of the superficial elements." (Foley 1977: 25)

Notice that phonetics and phonology are totally autonomous within Foley's (1977) view. There is certainly no doubt that this proposal pertains to the first radical view, since phonetic properties are not employed to characterize phonological components. In particular, he emphasizes that phonological elements should be independent of a subordinate phonetic definition to prevent what he believes is a philosophical error, reductionism, which ultimately makes phonological elements attain scientific status. In this sense, Foley (1977) seems to believe that we just have to learn the links between phonetic properties and phonological features, which leads us to regard them meaningless. If this is so, an important question can be asked: what is the status of phonetic facts? In phonological analysis, phonetic facts are irrelevant to phonological analysis and become useless without any function of them.

Let us now consider an example of the first abstract view of phonology. Employing the assumption that phonology and phonetics are different from each other, Fudge (1967) analyzes the vowels of Hungarian. Noting that vowel harmony is important to Hungarian, Fudge (1967: 10) adopts a symmetric vowel chart instead of dividing some vowels into mid and low groups, as illustrated in (3). Given that the specified low group combines mid vowels with low vowels, the low group can be described as non-high.

	Front			Back				
	Unro	unded	Rounded		Unrounded		Rounded	
High	i	i:	у	y:			u	u:
Low (non-high)	e	e:	ø	ø:	a	a:	0	0:

(3) Hungarian vowel system

In (3), there are no high back unrounded vowels. From a phonological point of view, it is, however, important to note that a front vowel /-i/, as the exponent of the plural affix, can be attached to both the stem with front vowels and the one with back vowels, as shown in (4).

(4) *i*-affixation in Hungarian (Fudge 1967: 10)a. /keze-i/ 'his hand'

b. /doboza-i/ 'his boxes'

In terms of vowel harmony, (4b) is not normal on the grounds that the non-harmonious front vowel is attached to the stem which is composed of all back vowels. Hence, Fudge proposes that the gap (High Back Unrounded) in (3) can be filled with the corresponding vowels, /i/ and /i:/ (Note: not /ö/ and /ö:/), having two places in (3): both High Front Unrounded and High Back Unrounded. It is now crucial that the phonetically front vowels are regarded as back vowels from the abstract point of view. The function of high back unrounded vowels is then fulfilled by these high front unrounded vowels which take over the gap. As Fudge mentions, the high front unrounded vowels are functionally back but phonetically front. In other words, they are used distinctively not in the pronunciation of them (high front unrounded vowels) but in the system of the language (high front unrounded vowels).

In addition, Vago (1976) has proposed a slightly different abstract analysis in handling this exception of Hungarian vowel harmony. One of the relevant examples is the case where a root with a front vowel takes back vowel suffixes, as shown in (5).

(5) Exception of vowel harmony in Hungarian (Vago 1976: 244)
a. hö:d 'bridge' + na:l/ne:l 'at' → à hi:d-na:l/\* hi:d-ne:l
b. hö:d 'bridge' + to:l/tø:l 'from' → à hi:d-to:l/\*hi:d-tø:l

Unlike Fudge (1967), Vago posits /ö/ and /ö:/ as the underlying representations of /i/ and /i:/, respectively. Since these underlying back vowels do not exist phonetically in Hungarian vowel system (Table 1), they have been called "abstract" vowel (Vago 1976: 245). He then assumes a rule of Absolute Neutralization to assign a phonetic feature [-back] to the abstract vowel roots (e.g., /ö, ö:/  $\rightarrow$  [i, i:]).

In both analyses above (Fudge 1967, Vago 1976), it is important to note that the lexical representations are not compatible with their phonetic features. For this reason, those analyses are typically identified as the radical abstract view that phonology is nothing to do with the various phonetic levels, such as the physical, articulatory, and auditory phonetic levels.

### 2.2 Unified Model of Phonetics and Phonology

Another view would be that phonology and phonetics are integrated into a single unit which is all phonetic. In this unified account, phonological components should be executed in quantitative phonetic values, which results from the idea that the area of phonology is equal to that of phonetics (phonology = phonetics). In this model, phonetic and phonological phenomena are best handled as a uniform component on the assumption that they are not discrete. Therefore, contrastive properties co-exists non-contrastive ones within the model. Given that under this view there is no difference between phonology and phonetics, no mapping is required between the two. This is consistent with Flemming's (2001) view that many similarities between phonetics and phonology should be explained by adopting a unified framework, as in (6):

- (6) a. "But it should be noted that the very existence of such uncertainty about the hypothesized dividing line between phonetics and phonology lends credence to the idea that the line does not exist." (Flemming 2001: 11)
  - b. "[…] there are many cases in which phonetic and phonological phenomena closely parallel each other. I have argued that the existence of these parallels is best analyzed as resulting from the phenomena having the same motivating constraints, and have outlined a unified framework for phonetics and phonology that allows for such an analysis." (ibid.: 39)

However, it is not clear to me whether phonological and phonetic properties are even considered the same or not within this unified framework. One possible interpretation for Flemming's claim would be that the division between phonetics and phonology should be ignored despite the presumption that they are different from each other in nature. The other would be that he assumes both phonetic and phonological properties are essentially the same. In my view, phonological features should be differentiated from phonetic features.

In contrast to the first radical position that phonetics and phonology are apparently separated, this model has been developed in a different way, coming to

another radical attitude. That is, phonetics and phonology are closely integrated in a single grammar, not simply interfaced, as advocated in Ohala (1990, 1997). Inherent in Ohala's view is that phonology should not be conceived as "an autonomous discipline," but it should encompass as much physical phonetics as necessary to give an explanation of human language. Since then, this position has been more radically developed in character by work which emanates, as Gussenhoven and Kager (2001) mention, from UCLA (Steriade 1993, 1997, Flemming 1995, 2001, Kirchner 1997, 1998, Hayes 1997) and Paul Boersma (Boersma 1998). The bottom line of their position is the criticism that while phonetic representations are by their nature complicated due to the interaction of physical and perceptual systems, phonological representations are stated more simply without specifying all the characteristics of phonetic properties (Flemming 1995). It is their main idea that the properties of phonology and phonetics are equally interpreted in a unified single module instead of two distinct modules (phonological and phonetic modules). More importantly, they attempt to endow phonological theories with more precise depictions of phonetics. The distinction between phonetics and phonology is erased by including all phonetic details into phonological representations. Accordingly, this idea, can be defined by the term "integrated theory" coined by Howe and Pulleyblank (2001).

On this view, the phonological elements, as argued by Steriade (1993, 1997), can be completely abandoned with the help of perceptual constraints as well as constraint hierarchies within Optimality Theory (OT). In general, she claims that features are licensed by perceptual cues rather than a phonological unit, prosody. This, however, can be disputed by categorical perception. As with the categorical perception, we can ask a critical question: why, if phonology is continuous, is perception of speech sounds categorical? For instance, if Voice Onset Time (VOT) is phonologically planned down to the milliseconds, why can't we hear it this way? For this reason, Steriade's claim cannot be maintained.

As a further consequence of the integrated theory, a unified model of phonetics and phonology makes it possible to employ scalar phonetic representation to allow for phonetic detail, which in turn results in phonetic enrichment of phonological representation (Kirchner 1997, 1998, Flemming 2001). Within this model, the discrete behavior might be characterized as a "threshold" effect which is an all-or-nothing property. In effect, the unified model considers that the threshold effect is not due to discrete representations but due to constraints (Flemming 1997). The basic idea of the unified model is that there is no difference in representations between phonetics and phonology. It is not the case that phonological representations are discrete as opposed to continuous phonetic representations. Both representations are instead continuous. However, constraints sometimes force us to pick out a set of categories in preference, which induces a discrete state.

Furthermore, the increased role of phonetic factors will make a separation of phonetics from phonology meaningless. A consequence of this view is the claim that phonetic elements fill exactly in phonological representation without any distinction between phonology and phonetics. This basic idea of the integrated theory is well expressed by Flemming (2001: 9):

(7) "Phonetics and phonology are not obviously distinguished by the nature of the representations involved, or in terms of the phenomena they encompass. As far as representation is concerned, most of the primitives of phonological representation remain phonetically based, in the sense that features and timing units are provided with broadly phonetic definitions."

In some ways, Flemming's statement in (7) does not go through. It is simply interpreted that phonology is a pretty good model of phonetics, which does not mean that phonology is the same with phonetics.

Boersma (1998) further supports this concept of the integrated theory, arguing for a "functional grammar" in which the grammar of languages is coordinated to facilitate human ease of articulation and perception. In his view, such a premise leads to a synthesis between phonetic and phonological approaches. He believes, for example, that "descriptions of the phenomena of phonology would be well served if they were based on accounts of articulatory and perceptual needs of speakers and listeners" (p. 467). Similarly, Hayes (1997) claims that the content of phonology is, to a great extent, arranged by phonetic functionalism through inductive grounding in which language learners can exploit the knowledge from what they have undergone during their articulation and perception.

## 2.3 Modular View: Mapping from Phonology to Phonetics

The last obvious possible view would be that phonetics and phonology are distinct from each other but that there is also a significant interaction between them. Within this position, there is a constrained (possibly parametric) mapping between phonology and phonetics, which implies phonological elements are universally related to phonetic ones to some extent. An attitude similar to this approach can be found in the Sound Pattern of English (SPE; Chomsky and Halle 1968), whereby phonological and phonetic representations are related by rules. The point is not simply that phonetics and phonology constitute separate levels: an abstract underlying representation vs. a concrete surface representation. Rather it is critically important that the general properties of phonological representations represent the best compromise between concrete phonetic transcription and abstract representation. Chomsky and Halle (1968) express this view in the following:

(8) "We therefore can represent lexical items neither in phonetic transcription nor in an arbitrary notation totally unrelated to the elements of the phonetic transcription. What is needed is a representation that falls between these two extremes. [. . .] We specifically allow the rules of the grammar [. . .]. Such rules are unnecessary in cases where the lexical representation can be accepted as the phonetic representation. In general, the more abstract the lexical representation, the greater will be the number and complexity of the phonological rules required to map it into a phonetic transcription. We therefore postulate abstract lexical entries only where this cost is more than compensated for by greater simplification [of the entire system]." (SPE; Chomsky and Halle 1968: 296)

Furthermore, a strong interaction between phonetics and phonology is advocated by "Laboratory Phonology." The most persuasive appeals to Laboratory Phonology may be the fact that it has attempted to discover the relation of phonetics to phonology more carefully, which in turn compromises the above two radical views for the most part. In much of the laboratory work, the idea is apparent that there is a dichotomy between phonetics and phonology, and thus phonological and phonetic representations are distinct from each other in that the former treats abstract formal units while the latter treats gradient phenomena. In other words, phonetics and phonology are dependent each other, but the dividing line between phonology and phonetics is not eliminated. It is also important to note that within most of Laboratory Phonology phonetics is regarded as an integral part of the grammar rather than outside of it, which makes it possible (even desirable) for phonetic measurements to provide evidence about formal representations and rules (see especially Keating 1988).

Under Laboratory Phonology, it is, in fact, impossible for phonological accounts to be properly evaluated without considering their consequences on other levels. Accepting the validity of Laboratory Phonology in this study, we believe that certain controversies between phonological accounts can potentially be resolved in terms that are phonetically testable. Thus, I argue that we need to accept a few premises to have this belief go through. First of all, it is necessary to find two theories that offer competing accounts in some way over a set of data. Second, the competing theories must make different predictions about the phonetic manifestation of a phonological feature or entity. Third, these phonetically motivated predictions must be measurable. Based on the predictions made by the competing theories, we are able to set up two different hypotheses which can be assessed by experiments. On the contrary, if two phonological accounts are not competing with each other and make the same predictions, we cannot decide between them based solely upon empirical tests of phonetic predictions. It is, therefore, particularly crucial to relate a phonological controversy at hand to a phonetically measurable quantity. If two phonological analyses make different phonetic predictions about the same phenomena, we can then go on to do phonetic experiments to see which prediction is more consistent with the experimental evidence (Chang 2002).

An extremely important point is that not every sort of phonetic information is relevant to phonological features, which is asserted by Anderson (1981) and Keating (1988). At best Anderson (1981:506) claims that "the phonological behavior of a linguistic element is not exhausted by its phonetic content, and indeed that its phonetic content is not directly predicted by its phonological character either." According to him, it is not true that underlying phonological components correspond to surface phonetic components in a straightforward way. With regard to the issue of naturalness, he also proposes that the phonological aspect does not have to be

equated with the phonetic aspect in that "a feature system which is directly and exhaustively phonetic in character will not in the general case lead to adequate descriptions of the sound patterns of natural languages" (ibid.: p. 503). Taken as a whole, his position is in the middle of the above two radical ones. Not only does he advise that we should not ignore phonetic information in the consideration of phonological representation, but he also emphasizes that a phonological feature system cannot be identified with a set of phonetic feature (ibid.: p. 506).

With this background, we now come back to the fact that these intermediate positions have been spurred on by the introduction of Laboratory Phonology, in which the relation of phonetics to phonology is more carefully contemplated. To quote Francis and Jones (1996: 383), "the primary methodological framework within which phonologists have attempted to develop representations which are phonetically testable is laboratory (or experimental) phonology." In order to figure out how phonological and phonetic elements are related to each other, Laboratory Phonology has introduced a new way of investigating language phenomena, "a hybrid methodology" in which experiments are designed to control for phonological structure (Beckman and Kingston 1990). In other words, the measurement of certain aspects of phonetic components should be done in experiments that acknowledge and consider phonological components and structures in their design. Otherwise, there is no way to observe whether there is any relationship between phonological and phonetic components.

With the assumption that "most people take Laboratory Phonology to refer to the interaction or interface of phonetics and phonology" (Keating 1994), Laboratory Phonology can be characterized by two beliefs. On the one hand, Laboratory Phonology believes that there should be still a division between phonology and phonetics. Instead of single module, it, therefore, posits two distinct modules: phonological and phonetic modules. On the other hand, there is also a strong connection between phonology and phonetics in Laboratory Phonology, which is represented by a considerable interconnection between the two modules. In this respect, Laboratory Phonology is in line with a "modular theory," as opposed to the integrated theory (Howe and Pulleyblank 2001).

#### 3. Towards the Modular View

#### 3.1 Abstract View vs. Modular View

If we follow the first radical position that phonetic and phonological features are strictly dissociated, an arbitrary categorization in phonology has to be presupposed, as SPE (Chomsky and Halle 1968: 169) pointed out:

(9) "It might be proposed, in light of the distinction between phonological and phonetic distinctive features, that the two sets be absolutely unrelated […] the rows be labeled entirely differently in the phonological and phonetic matrices. […] Only the phonetic features would now be "substantive"; the phonological features would be without physical content and would provide an arbitrary categorization. (SPE; Chomsky and Halle 1968: 169)

Before proceeding to an inquiry of the first view, it is perhaps better to contrast Foley's view with a rather different approach (i.e., Halle 1983) to the role of phonological features. While Foley acknowledges the fully autonomous nature of phonological classes, Halle (1983) maintains that "the abstract distinctive features constitute the link between specific articulatory and acoustic properties of speech sounds" (p.94). Thus, a consequence of Halle's view is the establishment of links between phonological features and phonetic properties, as schematized in (10).

(10) Relationship between phonological features and phonetic properties
 <u>Phonetics</u>
 <u>Phonetics</u>
 <u>Phonetics</u>
 <u>acoustic properties</u>
 <u>distinctive features</u>
 <u>articulatory properties</u>
 <u>(perception)</u>
 (production)
 (production)

In the above schema, phonology and phonetics are separated. However, they are also inextricably linked by the association line. In this respect, this model belongs to the third position that there is a separation with a principled connection between phonology and phonetics. What is critical to this model is of course the link between phonology and phonetics. This is because it leads to an account for both speech perception and speech production processes. According to Halle (1983:95), speech perception is related to the connection between acoustic properties on the left hand side of the diagram and distinctive features in the middle of the diagram. On the other hand, speech production is relevant to the interaction of distinctive features with articulatory properties on the right hand side of the diagram.

Although it has been generally agreed that we encode what we hear in our mental representation and employ this mental encoding to say something, the debating issue can arise with regard to the nature of the links between phonology and phonetics shown in (10).

What is problematic is arbitrary mapping between phonological features and phonetic features. Consider, for example, Lombardi's (1991) work which led to the development of the abstractness in phonology in that her criteria for the analysis are apparently associated with phonology alone without any connection with phonetics. Specifically, she proposes that the only laryngeal features that are needed for phonology are [voice], [glottalization], and [aspiration], which are privative features. With these features, the first criterion is that "this three-feature system makes all and only the necessary contrasts," and the second criterion is that "it makes the proper groupings for phonological rules" (p. 27).

Among these features, [aspiration] is relatively unproblematic in that its phonetic characteristic is clearly determined. The distinction between breathy voiced and aspirated consonants is attributed only to the feature [voice], which is also true phonetically. On the other hand, a number of problems could arise when we consider how [glottalization] should be characterized in terms of its combination with [voice]. Under Lombardi's proposal, the possible combinations of these features are given in (11).

(11) Feature combination

a. 
$$\begin{pmatrix} \text{voice} \\ \text{glottalization} \end{pmatrix} \longrightarrow \text{implosive} \qquad \begin{array}{c} b. & \emptyset \\ & glottalization \end{pmatrix} \longrightarrow \text{ejective/tense} \\ \end{array}$$

First of all, this analysis does not provide the definition of a separate feature

#### On the Relation between Phonetics and Phonology 141

since it employs a collection of features. Once we combine features for the implosive sound as (11a), there is no consistent definition of [voice] or [glottalization]. When we compare (11a) with (11b), the definition of [glottalization] is differentiated depending on the status of [voice]. That is, if [voice] is present, [glottalization] means an implosive in (11a). If not, [glottalization] means ejective or tense in (11b). In effect, features do not have such a conditional definition. They instead have their own definition so that [glottalization] means vocal folds press together. As a result, the feature combination turned out problematic due to the conditional way of definition.

Secondly, the combination of features in (11a) induces arbitrary mapping between phonological representation and phonetic representation. The features, such as [voice] and [glottalization] cannot be proper characteristics of implosives. In particular, the nature of non-pulmonic ingressive in implosives should be associated with [glottalization] because it is nothing to do with [voice]. Then, this phonetic implementation of [glottalization] cannot be found in (11b), since ejective and tensed sounds are relevant with the opposite airstream-mechanism, egressive. The empirical evidence is from Igbo, in which voiced implosives contrast with voiceless implosives.

Thirdly, the rule given in (11b) does not assume language universals because this feature set is realized as either an ejective for some languages or a tensed consonant for other languages. Acknowledging the problems thus far, I conclude that phonology should be more concrete than Lombardi's account with no conditional definition.

The simplest solution for these problems is to employ phonetic features from the beginning, instead of arbitrary features. This idea is the same as the second radical view that there is no mapping between phonology and phonetics. Of course, this view does not demand any kind of mapping rules from abstract phonological features to concrete phonetic features. Nevertheless, the reality is not so simple because SPE, at the same time, explicitly propose that phonological representations are not equal to phonetic representations. Although it is true that SPE disaffirms the arbitrary mapping between phonological and phonetic representations, it does not ignore all kinds of mapping relations between them.

According to SPE, phonological and phonetic representations are indeed related by rules. However, the rules employed here are different from the ones in (11) by nature. As I mentioned before, SPE takes the third position that phonetic features are mapped to phonological features in a parametric way. The rules are, therefore, demanded to have contrastive or privative features in the underlying representations be spelled out as some sorts of scales in the surface representations. The implication of this view is that any scale that exists phonetically will be quantized to become phonological features. In other words, phonology is interpreted as the outcome of quantization, making continuous phonetic features discrete. This relation is well represented by the following diagram in (12).

(12) Scaling and alignment with the phonetic details



It is thus crucial to note that phonological features should be created based on phonetic values of a sound, although the former are abstract in nature.

#### 3.2 Integrated View vs. Modular View

A major landmark in the emergence of Laboratory Phonology is Pierrehumbert's (1980) proposal of a phonological representation for English intonation and a proposal for phonetic rules that implement phonetic feature values. In terms of a separation between phonology and phonetics, Pierrehumbert first develops an abstract representation for English intonation at a phonological level with an emphasis on patterns rather than quantitative values. Thus, the phonological characterization of English intonation is analyzed as an association of discrete tone units (e.g., L and H tones) to the text through a metrical grid. It is then the continuous  $F_0$  contours that correspond to the phonetic representation. In addition, the contour is generated by a set of rules (e.g., "local context-sensitive rules" and "tone spreading") which are, as discussed by Keating (1988: 290), interpreted as phonetic rules rather than phonological rules due to the nature of their "quantitative evaluation." It remains

now for us to see how phonology can share phonetics in Pierrehumbert's (1980) analysis.

It should be noted that, in Pierrehumbert's proposal, the major role of the phonetic rules is to complete phonological representations with concrete phonetic values. Phonetics is often placed a priori outside of grammar, which makes phonology necessarily autonomous. Contrary to this traditional view, Pierrehumbert maintains that the phonetic representation, the output of the phonetic rules, is better characterized as linguistic (i.e., still mental) than as physical. As a consequence, the phonetically relevant component is assigned as part of the grammar, in addition to the phonology. What is critical to this view is that this approach presupposes even an abstract underlying representation, which is later translated into a concrete phonetic representation by phonetic implementation rules, such as interpolation rules (Pierrehumbert 1980 on English intonation, Beckman and Pierrehumbert 1986 on Japanese and English intonation, Pierrehumber and Beckman 1988 on Japanese tone, Cohn 1990 on the feature Nasal). Crucial to the role of the interpolation rules is the connection of phonetic targets which have been assigned based on the phonological specifications of feature values (e.g.,  $[+F] \rightarrow high target$ ,  $[-F] \rightarrow low target$ ) (see Cohn 1995). As a result, only a few syllables are specified as phonetic targets and the F0 of the remaining ones is derived by interpolation. This target-interpolation model is illustrated in (13).

(13) Target-interpolation model of phonetic implementation



Notice that the target-interpolation model in (13) yields intonational phonology,

in which the form of intonation is comparable to other component of phonological structure. A tonal entity that is contrastive is marked with the feature values in phonological output, and then it is realized as one of the phonetic targets (high or low). Pitch contour is finally implemented by interpolation.

The next question, then, is to discover how this model is different from the unified approach (the integrated theory). To answer this question, it may be useful to examine an alternative analysis (Kirchner 1997) on this interpolation phenomenon in which phonological representations contain complete phonetic detail. According to him, the effect of linear (or non-linear) interpolation is interpreted in terms of Optimality Theoretic constraint interaction. Specifically, candidates are first represented with numerical  $F_0$  values, and a constraint, LAZY plays an important role to select intonation contour as an optimal candidate, as shown in (14).

LAZY ····	•••						
450001		100	100	250	100	100	a. 100
45000:		σ	σ	σ	σ	σ	σ
19750		100	175	150	200	150	🖙 b. 100
18/50		σ	σ	σ	σ	σ	σ

(14) Optimality Theoretic reanalysis on interpolation (Kirchner 1997: 104)

As noted in (14), LAZY is evaluated over the two numbers which represent the articulatory effort. They can be calculated by "the sum of the squares of the difference between each  $F_0$  value and the following value in the array" (p.104). For example, the equations for the numbers in (14a) and (14b) are as follows: (100 -  $100)^2 + (100 - 100)^2 + (250 - 100)^2 + (100 - 250)^2 + (100 - 100)^2 = 45000$  in (14a);  $(100 - 150)^2 + (150 - 200)^2 + (200 - 250)^2 + (250 - 175)^2 + (175 - 100)^2 = 18750$  in (14b). Instead of (14a), LAZY correctly selects the candidate (14b) in which  $F_0$  values between two syllables increase or decrease more gradually.

Assuming the basic correctness of linear interpolation, we can compare the target-interpolation model in (13) and Optimality Theoretic analysis in (14). The distinctive property of the former is its representational characterization of abstractness: an abstract underlying representation. In other words, some features in the phonological output may be underspecified due to their non-contrastive nature. In

contrast, the latter employs neither underspecification nor post-phonological levels (e.g., phonetic targets and phonetic interpolation), instead it includes phonetic details in phonological representations from the beginning. We can, thus, conclude that the target-interpolation model is conceptually different from the integrated theory that purely depends on phonetics.

Given this difference between the two analyses, we need to decide which analysis is more natural and adequate to our mental process. Phonetically, it is impossible to examine which analysis is better than the other.<sup>1</sup> As a consequence, a conceptual argument can be made, instead of conducting phonetic or psycholinguistic experiments. With regard to the integrated theory, there are numerical values from the beginning. If so, we must answer the following question: what would be the reason not to store those numbers in speakers' memories? In my view, it is almost impossible to answer this question, which is problematic. On the other hand, the target-interpolation model does not allow such numbers in phonology. While phonology has nothing to do with measured numbers, phonetics deals with them. This model, thus, acknowledges that phonological representations are different from phonetic representation in a way that the former is discrete and the latter continuous.

With the difference between the two theories in mind, let us now return to the modular theory. As long as the contents of the two modules are not completely independent of each other, then the relationship between phonology and phonetics, I think, should not be arbitrary. Each field will influence the other in substantive ways. For instance, we will insist that there are no languages in which a phonological high tone is lower than a phonological low tone in terms of phonetic pitch value in the same environment. This more or less complicated context enables us to exclude an unwanted situation, such as downdrift in (15).

<sup>&</sup>lt;sup>1</sup> In fact, Arvaniti (2007) maintained that a unified account, by showing the phonetic data of pitch contour, failed to explain why Greek native speakers did not perceive the difference in the continuous F0 curves. Instead of perceiving phonetic details, they just abstracted away from the different pitch contours realized in different utterances and generalized them as the same overall phonological representation.

(15) Schematic representation of downdrift



As illustrated in (15), the last phonological H tone can be phonetically lower than the first earlier phonological L tone, since the rightward lowering of tones occurs repeatedly when H alternates with L in the phrase (Pierrehumbert and Beckman 1988). This downdrift process, however, should not be taken into consideration because the tones in (15) are not in the same environment.

In general, I would suggest that there is no reversal between phonology and phonetics. Ultimately, Laboratory Phonology has been developed on the grounds that phonology and phonetics can benefit each other from an array of phonetic data and testability of phonological hypothesis (Keating 1994). We can generalize this requirement further. Specifically, I propose the following fundamental principle about phonology-phonetics interface:

(16) Principle about phonology-phonetics interface

If we have two phonological representations, A and B, and A is more marked than B, then it should not be the case that the phonetic expression of B is more marked than the phonetic expression of A.

As was stated in (16), phonological representation is not arbitrarily determined but is influenced by phonetic properties. This perspective is further strengthened by the apparent fact that the higher pitch value of a tone compared with other tones is best characterized as a phonological high tone rather than a low tone. Relating to this issue, consider some possibilities for the realization of the two tones (H and L) in (17).

(17) Some possible phonological representations of tones relating to the phonetic pitch

higher pitch	Н	Ø	Н	* L	* Ø	* L
lower pitch	Ø	L	L	Ø	Η	Н

Among the six different possibilities, the shaded three cases are not good on the grounds that higher pitch is represented as comparatively lower features than lower pitch. This means that it does not happen that phonological features can reverse their features. However, that idea can be countered by the example of tone reversal in which the tones in certain dialect have the opposite values from those in others. In the followings, we will consider the Japanese and Athapaskan languages with reference to tone reversal, showing that tone reversal is nothing to do with tone change or the flip of tone.

# 3.3 Tone Reversal

In this section, we will consider the examples of tone reversal in which the tones in a language (including a dialect) seem reversed in the mirror because high tone in a language is realized as low tone in another language and vice versa. However, this phenomenon of tone reversal turns out to be a pseudo-counterexample to the principle about phonology-phonetics interface.

#### 3.3.1 Japanese: Narada and Tokyo Dialects

Among the dialects of Japanese, Narada and Tokyo dialects show an opposite tone melody, as illustrated in (18). As the data in (18) show, when a H tone is assigned to a vowel in Narada Japanese, the corresponding vowel in Tokyo Japanese always gets a low tone and vice versa. With regard to this mirror-image correspondence, some people may argue that an underlying tone undergoes the flip of tone, mapping the underlying tone into the opposite surface tone (e.g., H  $\rightarrow$  L or L  $\rightarrow$  H).

(18) Mirror-image correspondence in Japanese (Inagaki et al 1957, cited in Kim 1999: 286)

	Narada		Tokyo
a.	áràre-ga (HL…)	'hail'	àráre-ga (LH…)
b.	kágàmì-gá (HLLH)	'mirror'	kàgámí-gà (LHHL)
c.	kàbútò-ga (LHL…)	'helmet'	kábùto-ga (HL…)
d.	kókòró-ga (HLH…)	'heart'	kòkórò-ga (LHL…)
e.	kámìsorì-gá (HL…LH)	'razor'	kàmísorí-gà (LH…HL)
f.	kámàboko-ga (HL…)	'fish patty'	kàmáboko-ga (LH…)

However, the metrical account by Kim (1999) eliminates the unnatural tone mapping process (i.e., the flip of tone) successfully with the presupposition that tones are underspecified in the underlying representation. Rather than posing the different underlying tones between the two dialects, he suggests that there is no dialectal difference in the underlying and metrical representations of the data in (18). That is, both dialects have the identical metrical structures of the corresponding words without specifying tones in the underlying representation. Only the rules, which insert tones (H and L tones) to the underlying forms, are responsible for the difference in tone melodies. In other words, the environment of the H tone insertion rule in one language corresponds to the one of the L tone insertion rule in the other language and vice versa. Metrical tone, therefore, preserves "no flip" principle.

# 3.3.2 Athapaskan Languages

In addition to the Japanese dialects, diachronic tone reversal is also detected in Athapaskan languages (Rice 2000 on Slave (Hare) vs. Sekani, Kingston 2002 on Chipewyan vs. Gwich'in), and some representative data are given in (19).

(19) Tone reversal in Athapaskan languages (Rice 2000:2)

	Proto-Athapaskan	Slave (Hare)	Sekani	gloss
a.	ya'	yá' (H)	yà' (L)	'louse
b.	təts'	tε' (H)	tèl (L)	'cane'
c.	ts'a'q'	w'á' (H)	ts'à' (L)	'dish'
d.	tu	tù (L)	tú (H)	'water

Notice that the words with a high tone in Slave (Hare) are realized as a low tone in Sekani, as in (19a)—(19c). And also, a low tone is assigned to the word in (19d) in Slave (Hare), whereas a high tone is assigned to it in Sekani. To account for this problem, Rice (2000) argues that the two languages have different patterns of markedness in the underlying representation, as illustrated in (20).

	Slave (Hare)	Sekani
Underlying	H/Ø	L/Ø
Surface	H/L	L/H

(20) The different patterns of markedness between Slave (Hare) and Sekani

We observe in (20) that Slave and Sekani have different marked tones in the underlying representation: high tone is marked in Slave (Hare), but low tone in Sekani. Thus, either high or low tone should be marked, depending on language. In addition, the fact that the phonological contrast in Slave is a private one between high tone and no tone implies that low tone is phonologically inert because of its absence. In the similar vein, high tone, instead of low tone, is phonologically inert in Sekani on the grounds that only low tone is marked in the underlying representation. By employing different patterns of markedness, the tone reversal in Athapaskan languages now can be explained completely without reference to the flip of tone between phonology and phonetics.

We might then conclude that simple tone reversal is not a counterexample of the idea that there is no flip of tones in terms of phonological representation and phonetic representation. Without the tonal change (e.g., H à L or L à H), the mirror correspondence in terms of tone is explicable in both the Japanese and Athpaskan languages. It remains to complete the diachronic reconstruction of Athapaskan to discover whether any stage of Athapaskan showed a synchronic tone flip.

So far, we have observed three different views on the relation between phonetics and phonology: the fully abstract view, integrated view, and modular view. First of all, the fully abstract view takes the line that there is a sharp division between them. Conversely, the integrated view regards them as parallels within a unified framework. Unlike these radical approaches, the last modular view admits both a separation between phonology and phonetics as well as a strong connection between them, which leads us to suggest that its attitude is in the middle of them.

#### 4. Further Issues Related to the Phonology-Phonetics Interface

# 4.1 Speech Production and Perception

In chapter 3, I have proposed that phonetics and phonology are related to each other in a principled way, weighing the three different perspectives on the relationship between phonetics and phonology. This proposal is consolidated with the perspective of Laboratory Phonology that advocates the use of phonetic evidence.

In particular, the most direct way to assess a phonological analysis is to examine L1 speaker's production data. When two competing phonological accounts are attested, what is required is to determine which phonological account better correlates with phonetic evidence. As a way of illustrating the use of phonetic evidence, Chang (2002, 2005) introduces a representative phonological controversy regarding North Kyungsang Korean (NKK) tones. The tonal representations for stems in NKK are controversial with respect to the relative markedness of a word-final tone: lexically marked tone *vs.* unmarked tone. If we provide the phonetic evidence that marked tones are more prominent than unmarked, then the two different phonological analyses make opposing predictions about the relative pitch values for tones. The word-final tone is predicted to be either higher or lower than the other tones. The experimental results reveal that the lower final tone should be interpreted as an unmarked tone.

The same procedure, in which production data can be used to resolve controversial phonological theories, is extended to a perception process. First, it is required in speech perception that the observed competing theories a priori offer the possibility of different phonetic outcomes with each other, reflecting distinct hypotheses. For example, a certain theory [Theory A] predicts that phonetically distinct x and y should be perceived as the same (x = y), whereas the other theory [Theory B] hypothesizes discrimination between x and y  $(x \neq y)$ . And then, it is necessary to assess these two competing theories by simply conducting a discrimination task in which we can observe whether subjects perceive x and y identical or different. We may eventually interpret one of the theories as being more

likely to be right and the other as more likely to be wrong. We will support for Theory B ( $x \neq y$ ) when participants show a good performance in the task. On the contrary, Theory A (x = y) will be advocated when they show a poor performance in the perception task.

In addition to the L1 speech production and perception tasks, it is also meaningful to consider L2 learner's production and perception of a target language. Suppose that there are either the same or the different phonological features between the target language and their native language. Given that L2 speakers' perception and production of the target language relies on the phonological system of their native language, a better performance will be expected in their perception of the phonological features that are shared between L1 and L2 than those that are not shared between L1 and L2.

With regard to L2 perception task, Chang (2002, 2007) first points out that throughout the previous literature the relevant English laryngeal feature has been defined in a different way: either voicing  $[\pm voice]$  or aspiration  $[\pm spread glottis]$ . In order to resolve this phonological controversy, L2 perception task is conducted, and the performances on the English laryngeal contrast by two groups of L2 learners of English (Korean and Japanese groups) are compared. According to Chang, Korean participants show better performance on the perception of English plosives than Japanese participants. While Japanese plosives have a laryngeal contrast of voicing, Korean plosives are mainly distinguished by the degree of aspiration. Given this fact, it is concluded that English laryngeal feature is similar to the laryngeal feature of Korean stops, which is aspiration.

# 4.2 The Role of Speech Perception in Phonology

In section 4.1, we have seen that the data of speech perception can be useful in discovering the more appropriate phonological account among competing phonological theories. In this sense, speech perception assists phonology with the data from auditory phonetics. Let us now consider the somewhat more radical view that some pieces of information in speech perception create phonological constraints and determine their rankings.

Steriade (2001) observes that certain contrasts are more discriminable than others and that the same contrast is more salient in some positions than others. Based on this notion of "absolute and relative perceptibility of different contrasts," she establishes the P-map hypothesis. The P-map hypothesis is designed with the needs of resolving some problems in Optimality Theory, one of which is that there is no principle that determines the ranking of conflicting constraints. It is the P-map that helps to project correspondence constraints and rank them. Therefore, the structure of correspondence in Optimality Theory is determined by the perceived similarity. Steriade suggests that this perceived similarity is simply computed by comparing listeners' confusion rates. For example, a pair of sound [ba]-[pa] is judged to be more similar than another pair of sound [ba]-[ma]. The more similar the pair is, the more confused the listener is.

The table in (21) illustrates how the P-map constructs correspondence constraints and arrange these conflicting constraints in ranking order. In the post-vocalic position, the contrast between [b] and [m] is more distinctive than the contrast between [b] and [p]. The fact that [b]-[m] contrast is more salient than [b]-[p] contrast makes listeners difficult to perceive the latter contrastive sounds ([b]-[p]) as being different sounds. This may also explain why the alternation between [b] and [p] is more common across the languages in the world, and a relevant phonological rule would be that [b] becomes [p] after a vowel. Given that [b] is different from [p] in terms of voicing, Ident [ $\pm$ voice] has to be ranked low for [p] to be chosen as an optimal output.

(21) P-map effects on the ranking of correspondence conditions (Steriade 2001:5)

P-map comparisons	More distinctive contrast	Less distinctive contrast	
	(e.g. [b]-[m] in V_] vs.	[b]-[p] in V_])	
Ranking of correspondence	Higher ranked constraint	Lower ranked constraint	
constraints	(e.g. Ident [ $\pm$ nas]/ V_] >>	Ident [±voice]/V_])	

The P-map hypothesis is, however, criticized by Kabak and Idsardi (2004). In Korean, stops become nasals before a nasal consonant. Applying the P-map to this phenomenon, we can estimate Koreans will confuse stops with nasals and tend to perceive stops as nasals when they are followed by a nasal sound. Kabak and Idsardi argue that "perceived similarity" is calculated with reference to the index of discriminability, which must be the opposite of similarity. For example, the conversion of discriminability scores (A') on [k.m] versus [ŋ.m] into "perceived similarity" scores is made by the following formula (Kabak and Idsardi 2004:46):

p ([ $\cdots$ .m $\cdots$ ]| / $\cdots$ k.m $\cdots$ /) = 2 (1 - A ([ $\cdots$ .m $\cdots$ ], [ $\cdots$ k.m $\cdots$ ])) A' = 1 (perfect discrimination), p = zero (no phonological rule) A' = 0.5 (discrimination equal to chance), p = 1 (phonological rule)

Korean group's A' score on [k.m] versus [ŋ.m] is 0.97. Hence, the chance of becoming a phonological rule (i.e., [k] becomes [ŋ]) is calculated:

p ([ $\cdots$ .m $\cdots$ ]] / $\cdots$ k.m $\cdots$ /) = 2 (1 - 0.97) = 0.06 (6% chance of a phonological rule)

The results of their perception task reveal that Koreans can successfully discriminate [k.m] from [ŋ.m] with A' score of 0.97, which corresponds to 97% correct responses in the perception task. The perceived similarity scores also show that there is only 6% chance of becoming a phonological rule. Thus, the process from [k.m] to [ŋ.m] in Korean cannot be explained by Steriade's notion of perceptual similarity to input.

In sum, the P-map hypothesis is so radical that it does not cover the cases where speech production and perception do not match. The P-map is refuted by the argument that speakers do not perceive minor differences that are not contrastive. Instead of perceiving all the phonetic details, speakers categorize minor differences in phonetics as the same in phonological level even though they make a distinction in their production.

# 5. Conclusion

In an attempt to define how phonetics is related to phonology, Laboratory Phonology has been recently developed with a somewhat neutral attitude. In Laboratory Phonology, it is mainly assumed that there is an apparent division between phonology and phonetics, but they are, at the same time, strongly connected to each other. Consideration of this view leads us to maintain that the most desirable grammar should be the one which reflects both phonological components as well as phonetic components.

The validity of this phonology-phonetics interface is enhanced by the fact that there is no flip of tones between phonology and phonetics. This, of course, implies that the nature of phonological features is circumscribed by phonetic facts. That is, phonological features are not arbitrarily determined. They, instead, should reflect what the phonetic fact is. On the basis of this non-radical view (phonetics  $\approx$  phonology), the principle of about phonology-phonetics interface is proposed in which there is no markedness reversal between phonological representations and phonetic expressions. Neither of the other radical views is relevant to this idea. If phonology is not related to phonetics, phonetic facts are completely meaningless in confirming a phonology to phonetics.

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Received: 2012. 03. 12 Revised: 2012. 04. 23 Accepted: 2012. 04. 23