Montague Phonology: A First Approximation

MONTAGUE PHONOLOGY: A FIRST APPROXIMATION

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0. Introduction. In recent years, an approach to natural language first developed by the philosopher Richard Montague has attracted considerable attention. In this paper we wish to explore in a preliminary way the problem of incorporating phonology into this framework, which has come to be known as Montague Grammar.

There are two sorts of questions one might ask. The first is this: given the general form of linguistic descriptions of grammars provided by Montague's general theory, how could they be modified or extended to include phonology? A not very interesting answer to this question would be provided by taking the entire apparatus of traditional generative phonology (in one of its current versions) and welding it onto a Montague Grammar.[1] A more interesting question, we feel, is the following: does Montague's general theory and later more restricted versions of it lead us to look at phonology in ways that are significantly different from the views of generative phonology? We believe that the answer to this question is Yes.

In Section 1 we sketch some of the differences between Montague grammar and various other theories. In Section 2 we make some initial proposals about a theory of phonology that would be consonant with the syntax and semantics of Montague grammar. Section 3 is devoted to showing how our approach might handle a fairly complex set of facts in Korean. Our tentative conclusions are drawn in Section 4.

1. Montague Grammar. Just as in the transformational tradition, there is considerable variation among writers in the Montague tradition, so that the term "Montague grammar" is actually a cover term for a collection of loosely related theories. We follow here especially the recent work of Dowty, Partee, Thomason, and Cooper (see references under these names).

We take a Montague grammar to be a direct, simultaneous recursive definition of the sets of well-formed expressions of the syntactic categories of a language and an assignment to each expression of a set of interpretations (in a model). This view of a grammar is to be contrasted with the assumptions made in the transformational-generative tradition. A transformational grammar is an indirect definition of the sets of expressions in a language and their interpretations. The central notion in transformational theory (and any generative theory in the tradition of Chomsky) is that of

a derivation. The characterization of a language is indirect in the sense that the rules are applied to strings or structures most of which are not "in" the language at all. The intermediate stages of a derivation have no interpretation.

This is a simple difference, but one which has far-reaching consequences, as we shall see. Among the more particular assumptions embodied in our view of Montague grammar are the following:

1. The wellformedness constraint (Partee, 1979): Complex elements are built up out of well-formed parts.

2. There are only three sorts of rules: those which tell what the basic elements are (including lexical rules of word-formation and inflection); the rules for putting them together into well-formed complex expressions; the rules of interpretation. (Just as in transformational theory, it is of course necessary to look for a highly constrained set of allowable syntactic operations).[2]

3. Compositionality: the form and interpretation of an expression is a function of the form and interpretation of its parts.

The above assumptions have among others the following consequences.

4. There are no obligatory rules, in the sense of rules that must apply to an expression before it becomes well-formed.

5. Hence, there can be no abstract elements which are deleted everywhere (e.g. labeled brackets, boundary markers, etc.).

6. Hence, no rules can refer to abstract structures, but only to the actual composition of an expression (hence, no transformations).

7. Since there are no generative rules in the sense of a transformational grammar, questions about extrinsic ordering cannot arise. The only ordering results from ordering between components (syntax before semantic interpretation) and from intrinsic connections among definitions.[3]

Thus, it seems that Montague grammar, under the restrictions adopted here, is an extremely constrained, perhaps too constrained theory of syntax and semantics. Note that the above assumptions and consequences imply many specific hypotheses that have been put forward in recent years: the elimination of boundary markers, a strict lexicalist syntax, no transformations, no extrinsic ordering.

2. What is Montague phonology? What happens when we approach the phonology of a language in the spirit of the restricted theory just outlined? In this section we will propose a view of phonology modeled on such a theory. We take the central task of the phonology to be an assignment of phonetic interpretations to "phonemic" expressions. In the phonology, the recursive definitions specify how the phonemes of the language may be combined to form well-formed expressions, which are in turn interpreted by the rules of

phonetic interpretation. Thus, the grammar as a whole becomes a system of recursive definitions of syntactic objects and two kinds of interpretations: semantic and phonetic.

We will approach this task in the following way. We first define sets of well-formed expressions at successive levels of a phonological hierarchy. This amounts to giving the syntax of a certain language in the technical sense. The expressions of this language, starting with the basic elements (the segments) are assigned phonetic interpretations (we will not actually give such an interpretation in our examples, but follow the usual linguistic practice of providing for a mapping into a phonetic representation through the use of distinctive features). We must then state a procedure for picking out the expressions in this phonological language which correspond to the actual expressions listed in the lexicon and put togeteher by the grammar of the language. There is a natural division in the grammar between the rules of the syntax and the rules associated with the lexicon, which include rules of word-formation (derivation and compounding) and rules of inflection. We'll take up each of these aspects of the theory in turn.

2.1 The phonological hierarchy. Recent work in standard generative phonology and metrical theory has shown that the hierarchical organization of the segments in a string plays an important role in phonological descriptions. The levels of representation which have been posited include: the syllable, the foot, the phonological word, and the phonological phrase.[4] A major part of the phonology is a series of definitions of well-formed units in this phonological hierarchy. We will use for this purpose, however, neither tree diagrams nor phrase-structure rules but rather a categorial system of the sort originally proposed by Ajdukiewicz (1935) and extended in various ways by later writers.

In a categorial system, every basic element is assigned to a category. There are two kinds of categories: arguments and functions. Complex elements are built up by putting together an argument and a function of the right sort. For example, in the syntax of English, determiners are assigned to a category (NP/CN) that takes a common noun phrase on its right to make a noun-phrase. We follow Lambek (1961) in using the following scheme:

i. a list of primitive categories (say, a, b).

ii. if a and b are categories, so are a/b and b\a.

a/b is the index of a set of elements that take members of the set of elements indexed by b on the right to make an element of the set a (and similarly for b\a with "left" for "right").

The basic elements of the phonology are the segments or phonemes. Out of these are constructed higher units and subunits. For example, in English (Selkirk, ms.) syllables consist of sequences of segments: stress feet consist of sequences of syllables; simple words consist of sequences of stress

feet, etc. (See Wheeler (1981) for a discussion of English stress in this framework.)

Our reasons for choosing a categorial framework are not simply a matter of taste. We believe that there are several automatic consequences of adopting a categorial framework. For example, independent labelling conventions are needed in the standard metrical theory to assign strong or weak to the nodes of metrical structures to account for the relative prominence of vowels in a word (or phrase). It seems to be a general principle of English stress that, assuming a categorial framework, arguments are interpreted as strong relative to their functions. Thus, relative prominence is a consequence of the function-argument structure of a string, and it is not necessary to posit any independent labelling conventions (See Wheeler, 1981, for further discussion of the excessive power of labelling conventions). Of course, it is necessary to find as many independent motivations for the assignments of elements to categories as possible.[5]

We will use the following kind of notation. Every combinatorial rule will be given in the following form:

A = A/B B or A = B B\A

Where necessary, special conditions will be stated with reference to the sets of elements mentioned in the rule. It's important to note that these conditions are simply abbreviatory conventions for sets of context-free rules. We'll illustrate the system by an (incomplete) description of Korean syllabic structures.

Following Kim (1976) we assume the following set of basic segments (we'll take up below how we interpret the notion of basic segments);

Consonants

Obstruents:	p	t	k	c	s		(plain)
	ph	th	kh	ch		h	(aspirated)
	pp	tt	kk	cc	ss		(tense)
Sonorants:	m	n	ŋ				(nasals)
	l						(liquid)
Vowels and Semi Vowels:	w	y					(glides)
	i	u	ɨ	u			
	e	ŏ	ə	o			
	ä		a				

We use digraphs for convenience, but consider ch, tt, etc. to be unit phonemes.

The categories necessary for describing the set of possible syllables are these:

Σ : the set of open syllables;
Σ' : the set of closed syllables;
N : the set of nuclei;
V : the set of vowels:

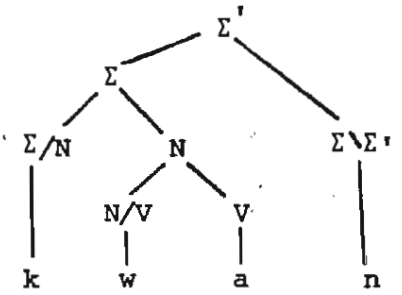
From these primitives we construct the further categories:

N/V: the set of glides (y,w)
Σ/N: the (true) consonants (onsets),
$\Sigma\backslash\Sigma'$: the sonorant consonants and plain stops (codas)

The syllable rules are the following:

1. $\Sigma' = \Sigma\ \Sigma\backslash\Sigma'$
2. $\Sigma = (\Sigma/N)\ N$
3. $N = (N/V)\ V$

(We ignore syllables with two vowels (or long vowels), which are limited to word-initial position.) Further syntactic constraints are stated as conditions on these rules. They are relatively few (having to do with glide+vowel constraints) and we will ignore them here. This reflects the fact that the above analysis is largely motivated by splitting things into maximally independent constituents and stating constraints as locally as possible. The rules claim that a syllable like kwan is built up as suggested in this picture:



There are two claims made by this picture of Korean syllable structure that might be considered controversial.

First, we consider the glide in a syllable like kwan to form part of the nucleus rather than being part of a complex onset. The main reason for this choice has been mentioned already. There are no constraints on initial consonants and following glides but there are constraints on glide+vowel sequences. If we choose to combine initial consonants and glides then we would have to distinguish between different types of onsets at the next level in order to get the right combinations. For example, the glide w may not precede u, and so the recursive definitions for would have to stipulate that an onset with w (let's say it belongs to the category Σ/N') could not combine with a vowel of the category u. Thus, this is a straightforward argument based on (a non-technical notion of) simplicity.

Second, we consider the coda to be something tacked onto an open syllable to make a closed syllable. This is opposed to the popular idea that the nucleus and coda make up a special constituent called the Rime, although it is not clear to us whether such a constituent is held to be universally necessary. We don't want to make any claim about languages like English, but for Korean it seems that the structure implied by our definitions has something to be said for it. Korean is a language of the sort in which the favored syllable type is CV and when syllables are put together into higher units (phonological words and phrases) final consonants are always assigned as onsets to following syllables beginning with vowels. We take this to be a reflection of the looser connection between the coda and the rest of the syllable illustrated in (ii) as compared to the alternative pictured in (i). Note also that a parsing procedure going from left to right requires less reanalysis under alternative (ii).

(i)

(ii)

In any case, none of the arguments that have been given for the rime in English are applicable to Korean. The arguments have been of two types: (1) phonotactic (like our argument for the onset and nucleus above), (2) arguments based on stress. As to the first, there appear to be no constraints on nuclei and codas in Korean. As to the second, there is no stress in Korean.

2.2 Lexical phonology. In our view of grammar, lexical entries are ordered n-tuples. Among the elements of these n-tuples are at least the following: a name or indication of the morphemic (lexical) identity of the item, a syntactic category, a translation into intensional logic, various syntactic and semantic features, and, in particular, for our purposes, a phonological representation giving all the information necessary for assigning a set of correct phonetic interpretations to the item in various contexts. Note that this representation will in general include the categorial assignment of the segments (an analogue in our framework to Selkirk's structured lexical entries (Selkirk, 1980). We assume that there are two sorts of rules associated with the lexicon: (1) rules which serve to extend the lexicon (word-formation rules in the sense of Dowty, 1978; Aronoff, 1976); (2) rules which provide the correct inflectional forms for combination into sentences by the syntax. This much seems completely uncontroversial. We assume further that many of the kinds of phonological rules set forth in studies like Chomsky and Halle, 1968, are associated with the lexicon.

A word-formation rule is basically a rule of the following form:

A. If α is a member of B_A, then α' is a member of B_B, where α' is the result of applying some limited set of operations on α (e.g. affixation of various sorts, perhaps no change at all)

We will treat certain kinds of phonological regularities in exactly the same way. That is, we assume that lexical entries are given wherever possible in a basic phonological form and that rules of the form A are used to provide predictable or automatic alternants. Choice of alternant is guided by the well-formedness conditions for the level in question.

Here's a straightforward example of how this works, taken from Cairene Arabic (Broselow, 1974). From the characterization of well-formed phrases in Cairene, it follows that sequences like these can't occur within a phrase:

CCC
CVCiCV

In a generative treatment, these facts are accomodated by rules of epenthesis and high-vowel deletion, which lead to derivations like this:

	/...VCCCiCV.../
Epenthesis	...VCCiCiCV...
HVDeletion	...VCCiCCV...

Intermediate stages of the derivative contain strings which are not well-formed expressions of the language.

In our framework we have the following two redundancy rules in the lexicon:

1. If α has the form /...VCC/ then there is an automatic alternant with the form /...VCCi/.

2. If α has the form /CiCV.../, then there is an automatic alternant with the form /CCV.../.

(These are short for rules that can be given precisely in the form of A.) Now given two lexical forms which are to be put together by the syntax we have the following situation:

	Form I	Form II
Basic form	CVCC	CiCVX
Automatic Alternants	CVCCi	CCVC

In this case, precisely one of the four possible combinations is allowed by the well-formedness conditions, namely the one in which we combine the two automatic alternants. Any other combination would lead to sequences which violate the well-formedness conditions. This is the ideal situation. However, it isn't quite enough for all situations and we will propose below a subsidiary principle which requires the choice of basic alternants wherever possible.

Not all alternations are automatic. Another major class of alternations are those in which alternant forms must be listed, but in which the choice of alternant is completely determined by the well-formedness conditions. In Korean, for example, any legal substring of a well-formed word can be a morpheme (or lexical item). In particular, this means that there can be formatives ending on clusters of (at most) two consonants: e.g. ops 'to not exist', ilk 'read' and so on. Since these and other similar morphemes can be combined with morphemes beginning with consonants (and sometimes occur in isolation) something has to go. But as far as we can tell, it is not possible to predict which consonants will drop out.[6] Thus, we simply list the alternants (op, ik) in the lexical entry. But again, the choice of the alternant is completely determined by the definitions of well-formed elements of the higher levels (and by the subsidiary principle).

Finally, there are formatives which exhibit alternant forms whose choice is phonologically determined, but not by appeal to well-formedness. For example, in Korean the nominative or subject case marker has two forms -i and -ka (the former occurring after consonant-final formatives, the latter after vowel-final ones: salam+i 'human being' uri-ka 'we'). There are a large number of such alternants in Korean (like a/an) in English). We aren't prepared to propose any universal conditions for such choices, but simply note that in Korean the choice is always determined by asking which choice leads to the less-marked syllabic structure: although salamka is not an impossible sequence in Korean, choice of the -i alternant yields an unmarked CVCVCV structure; while choice of -i for uri would lead to a marked VV sequence.

We've discussed one type of lexical redundancy rule, in effect, a kind of allomorphy rule. We're not prepared to say very much here about the rules of word-formation and inflection, except to note that the sorts of rules that pay attention to morpheme boundaries must be included, in our framework, in the rules associated with derivation and inflection.

2.3 Phonetic interpretation. We've talked so far about the phonological grammar and said something about our views of how to handle certain kinds of alternations and morphological processes. To complete our picture, we need to set forth a theory of how phonetic interpretation takes place.

We will make the following assumptions about phonetic interpretation:

1. Interpretations are given as "early" (locally) as possible.

2. Except for cases of optional interpretation, distinct phonetic interpretations must be distinctly represented in the phonologival specification of lexical items.

3. Specifications can't be changed; that is, if a segment is given a phonetic interpretation (specification) along a certain parameter, then it can't subsequently be given a different interpretation along that parameter (only a more fully specified interpretation).

We won't try to motivate the above assumptions fully here. But, (1) can be argued for on grounds of simplicity. (2) seems to be almost a truism. (3) seems to follow just from the nature of interpretations: It doesn't make sense to re-interpret an interpretation. The phonological language has to be interpreted. If every segment could be interpreted uniformly and fully from the start, then there would be nothing more to say. But it seems to be a part of the nature of phonology that part of the interpretation of segments is context-dependent. This is especially true of allophonic alternations. E.g. a stop doesn't receive an interpretation independently of the following (or preceding vowel), rather its interpretation varies according to what the vowel is.

The above assumptions lead to certain consequences. The one consequence that departs the most from current practices of generative phonology is that some segments are incompletely specified in lexical forms. Principle (3) taken together with this consequence leads us to state certain rules of phonetic interpretation in a maximally simple way. We'll see how this works in detail in the next section, where we take up a fairly complex set of alternations in Korean. For now, we'll just cite some cases where this idea seems to lead to interesting results.

(As far as we know, the arguments against exploiting the difference between incompletely specified segments and specified ones are internal to theories that share assumptions about phonology that we are calling into question, in particular, assumptions about a simplicity metric and misuse of features in collapsing rules.)

Case 1: Finnish vowel harmony. In Finnish, certain vowels (e,i) are impervious to vowel harmony, but trigger vowel harmony when they occur in the first syllable of a word. If we assume that these vowels are completely specified as to frontness whenever they occur, rules of vowel harmony can be stated in a completely general way. Principle (3) will prevent respecification of e and i as to frontness (backness). Further, the vowel harmony rules, stated in the maximally simple way, will make incompletely specified vowels agree with i and e in frontness when they stand in the triggering environment. (This example is highly oversimplified.)

Case 2: Nasalization: (This relates to our discussion of rimes above.) Consider a language in which vowels are nasalized when the coda is a nasal. If only vowels (elements in the nucleus) are unspecified as to nasality, we can just say that when the nasal coda is added to a syllable, the entire syllable becomes nasalized. Only the vowels will be affected).

Case 3: Nootkan vowels: Sapir and Swadesh (1939) set up three classes in Nootka (cf. Jacobsen, 1971 for some other Nootkan languages): basically short, basically long and 'variable'. Variable vowels have the property that they are long if they occur in the first two syllables of a word, short elsewhere. Variable vowels are indistinguishable from long and short vowels when they occur in these two environments. Since the length of the variable vowel is contextually determined, in our system, they must be uninterpreted (unspecified) for length in the underlying representation. We can now state a perfectly general rule specifying length for vowels in these two environ-

ments. Only the variable vowels will be subject to this rule since other long and short vowels are underlyingly specified for this feature.

We want to claim that wherever possible variations among segments are stated as rules of phonetic interpretation. But, given our assumptions, some alternations can't be handled in this way, and hence must be handled by the rules of allomorphy mentioned in the last section. We'll say more about this in the next section (and for more discussion, especially as our theory relates to markedness theory, see Wheeler, 1981).

3. Some Problems in Korean Consonantal Phonology. We have sketched out a view of how we want to approach phonology in a Montague grammar. In this section we want to show how our theory can handle a relatively rich array of alternations and allophonics in Korean.[7]

We will confine our attention initially to the following facts, which for expository purposes we set out using the descriptive vocabulary of a generative phonology with boundary symbols.

1. Obstruent neutralization. Before word-boundaries or consonants obstruents are replaced by their plain stop congeners:

Isolation form	+i (subject case)
ikot 'this thing'	ikosi
kkot 'flower'	kkochi

2. Lateralization of n: n + l = l + n = ll

chul + nap	chullap 'account'
kun + lək	kullək 'military power'

3. Obstruent nasalization: obstruents (or plain stops by (1)) are replaced by their nasal counterparts when followed by sonorants (or nasals, depending on the relation to (4) below):

kkoch + man	kkonman 'only'

4. l is replaced by n after an obstruent (stop) (or alternatively after a nasal, depending on the relationship to (3) above:

kak + lyo	kaŋnyo 'cabinet member'

5 Plain obstruents are tensed after obstruents (stops) or (optionally) sonorants.

op + ta	optta 'doesn't exist'

6. Clusters of h plus plain obstruent (in either order) are replaced by the aspirated congener of the obstruent:

coh + ta	cotha 'good'
mək + hi	məkhi 'eat + passive'

A typical solution in a generative framework using extrinsically ordered rules for facts (1) - (4) might look like this:

R1. Obstruent neutralization:

$$[+\text{obst}] \rightarrow \begin{bmatrix} -\text{cnt} \\ -\text{str} \\ -\text{tns} \\ -\text{asp} \end{bmatrix} \quad / \quad \_\_\_ \begin{Bmatrix} C \\ \# \end{Bmatrix}$$

R2. Lateralization of /n/:

$n \rightarrow l \; / \; l$ (mirror image)

R3. Stop-nasalization:

$[+\text{obst}] \rightarrow [+\text{nas}] \; / \; \_\_\_ \; [-\text{obst}]$

R4. Nasalization of /l/:

$l \rightarrow n \; / \; [+\text{nas}] \; \_\_\_$

Examples of derivations of medial clusters using these rules follows:

Phonemic	ch n	ln	nl	lm	ml	tl	tn
R1.	t n	--	--	--	--	--	--
R2.	--	ll	ll	--	--	--	--
R3.	nn	--	--	--	--	nl	nn
R4.	--	--	--	--	mn	nn	--
Phonetic	nn	ll	ll	lm	mn	nn	nn

These are the correct outputs. R2 and R3 are crucially ordered, the opposite order would incorrectly convert tl into ll. Similarly R2 must be ordered before R4 or else we would get nn from nl.

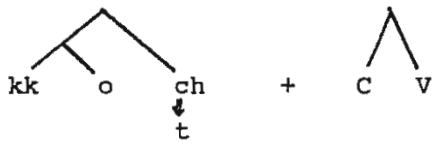
Before taking up our solution, which eliminates the need for extrinsic ordering of rules, let's note that there is a kind of puzzle in the facts involving sequences of stops and l. In the solution given above, there is one apparently arbitrary rule turning a stop into a nasal and then a natural rule of nasal assimilation (which must however be bled by the lateralization rule). Alternatively, we could turn l into n first and then have a natural obstruent assimilation rule. The choice seems largely arbitrary.

Our solution makes use of two lexical redundancy rules and three rules of phonetic interpretation. We are assuming, following Wheeler (1981), that the relatively unmarked values of features are left unspecified in the lexical representations of segments. Our assumptions about the initial

interpretations of the basic lexical segments can be seen in the following table. We are only concerned with those features which are relevant for describing the alternations described in R1-R4 (the reader will be able to extrapolate easily to the rest of the segments). We are assuming that the unmarked value for the feature obstruent is +obstruent for consonants, that the unmarked value for nasal is -nasal for obstruents and +nasal for non-obstruent consonants, and that the unmarked value for all other features listed is -F (following Kean 1975).

	th	tt	t	ch	cc	c	ss	s	m	n	n	l
cons	+	+	+	+	+	+	+	+	+	+	+	+
obst									-	-	-	-
tns		+			+		+					
asp	+			+								
cont							+	+				
str				+	+	+	+	+				
nas												-

Following Partee's well-formedness constraint, we assume that well-formed expressions at each level are derived by combining smaller well-formed expressions of the appropriate category. In Korean, the set of consonants belonging to the category $\Sigma\backslash\Sigma'$ (codas) consists of the plain stops, nasals, and l. A syllable with a final aspirated or tense stop is not a possible syllable in Korean. The following derivation, including obstruent neutralization, is not possible in our theory because it would violate the well-formedness constraint



Alternations like obstruent neutralization are consequences of the phonotactic constraints of Korean. There is no way to assign a phonetic interpretation to /kkoch + CV/ since ch is not a member of the category $\Sigma\backslash\Sigma'$ and so the segments could not be combined by the recursive definitions.

Recall that the rules of phonetic interpretation apply to expressions generated by the (phonological) syntax. Thus, obstruent neutralization must be viewed as a lexical process. We will treat the replacement of initial l by n in the same way. These two alternations are described by the lexical redundancy rules given below.

LR1: If a formative ends on an obstruent, it has an automatic alternant ending on the homorganic plain stop.

LR2: If a formative begins with /l/, it has an automatic alternant with /n/ replacing /l/.

Note that even if ch were possible in the coda, the neutralization rule that could be required (ch → t) would violate the invariance condition

since ch is specified for the more marked feature [+aspirated] and t is

Choice of alternant under LR1 is guided by the characterization of well-formed words and phrases, in part. That is, a sequence like /kkochman/ can't be a well-formed anything, since it is not phonotactically well-formed, so that alternant kkot must be chosen. But since plain stops can be onsets as well as codas, we need to say something more in order to keep from generating kkoti from kkot + i. For all such cases, we appeal to a fairly natural principle:

P1. Select basic forms where possible.

(This amounts to saying that distinctions will be kept maximal, consistent with the well-formedness conditions.)

Choice of alternant under LR2 is guided by a constraint on medial clusters: in giving the rules for constructing phonological words out of syllables we must require that if the first segment of a syllable is l then the last consonant of the preceding syllable must be l or n (i.e. a homorganic sonorant).

The effect of the above redundancy rules will be to give us the following sorts of medial clusters in words and phrases:

tn nl ln ll mn pn lm *tl *ml

As we mentioned earlier, we are assuming that phonetic interpretations are given as "early" (locally) as possible. In general, the values of non-alternating features may be specified as the segments are combined to form well-formed syllables. However, because of the invariance condition and the fact that certain aspects of the interpretation of segments depends on information outside the domain of the syllable, certain features must be left unspecified even at the syllable level. For example, the nasal consonants /m/ and /n/ may be specified for the unmarked value [+nasal] as soon as they are combined with a vowel to form a syllable because they never alternate with non-nasal segments. On the other hand, /n/ may not be specified [+nasal] at the syllable level because it is neutralized to /l/ before or after an /l/ (R2). If it were interpreted as [+nasal], the invariance condition would prevent the reinterpretation of the feature and the assimilation could not take place. Thus, as segments are combined to form syllables the following non-alternating features may be specified by the rules of phonetic interpretation.

	th	tt	t	ch	cc	c	ss	s	m	n	n	l
cons	+	+	+	+	+	+	+	+	+	+	+	+
obst	+	+		+	+	+	+	+	-	-	-	-
tns	-	+		-	+	-	+	-	-	-	-	-
asp	+	-		+	-	-	-	-	-	-	-	-
cnt	-	-	-	-	-	-	+	+	-	-		+
str	-	-	-	+	+	+	+	+	-	-	-	-
nas	-	-		-	-	-	-	-	+	+		-
voice	-	-		-	-	-	-	-	+	+	+	+

As syllables are combined to form words in Korean, various assimilation processes take place. In addition to the two lexical rules LR-1 and LR-2, three rules of phonetic interpretation are needed to account for the facts discussed earlier in (1)-(4). These rules are given below.

PI-1 $[+\text{cons}] \rightarrow [-\text{obstruent}] \; / \; \_\_\_ \; [-\text{obstruent}]$

PI-2 $[-\text{obstruent} \rightarrow [-\text{nasal}] \; / \; \_\_\_ \begin{bmatrix} -\text{obstruent} \\ -\text{nasal} \end{bmatrix}$ (mirror image)

PI-3 $[-\text{obstruent}] \rightarrow [+\text{nasal}] \; / \; [+\text{nasal}] \; \_\_\_$

Note that the effect of PI-1 is to make the plain stops, which are specified as noncontinuants, into noncontinuant sonorants, which by universal laws, must be nasals, since /n/ is unspecified for the feature continuant it will not be marked for nasality by the linking conventions. There is no extrinsic ordering necessary among PI-1 - PI-3. We assume that these rules apply freely whenever their structural description is met. In the standard analysis, rule (R2), (corresponding to PI2) had to be ordered before the rule (R4) (corresponding to PI-3) to prevent the following incorrect derivation:

*/nl/ $\rightarrow$ [ll]

(PI-2) and (PI-3) do not need to be extrinsically ordered. Recall that we are assuming that /n/ is unspecified for the feature nasal and so PI-3 may not apply to /nl/. Note further that PI-2 cannot affect /m/ and /n/ since they are already specified as +nasal .

These rules give the correct outputs:

	tn	nl	ln	ll	mn	pn	lm
PI-1	nn					mn	
PI-2		ll	ll				
PI-3	nn				mn	mn	
	nn	ll	ll	ll	mn	mn	lm

Now we will take up some further facts having to do with phonetic interpretations. They include the tensing and aspiration rules for plain stops as well as the distribution of allophones of s and ss, voicing, and cluster simplification. First of all, obstruents become tense following a consonant.

PI-4 $[+\text{obst}] \rightarrow \begin{bmatrix} +\text{tns} \\ -\text{asp} \end{bmatrix} \; / \; C\_\_\_$

This rule is optional where C is a sonorant (moreover, it applies within phonological words obligatorily, optionally within phrases which to us suggests that it is a rule that applies within phonological words, and that the optionality of it is dependent on the optionality of phrasing).

PI-5 $\begin{bmatrix} +\text{obst} \\ \alpha F \end{bmatrix} \begin{Bmatrix} +\text{obst} \\ +\text{tns} \\ \alpha F \end{Bmatrix} \Rightarrow \begin{bmatrix} +\text{obst} \\ +\text{tns} \\ \alpha F \end{bmatrix}$

PI-6 $\begin{Bmatrix} \text{obst} + \text{h} \\ \text{h} + \text{obst} \end{Bmatrix} \Rightarrow \begin{bmatrix} +\text{obst} \\ +\text{asp} \end{bmatrix}$

PI-7 $[-\text{cnt}] \rightarrow [+\text{voice}] \;/\; [+\text{voice}] \_\_ \text{V}$

PI-8 $\text{l} \rightarrow \breve{\text{r}} \;/\; \text{V} \_\_ \text{V}$

PI-9 $\begin{Bmatrix} \text{s} \\ \text{ss} \end{Bmatrix} \rightarrow [+\text{palatal}] \;/\; \_\_\_ \begin{Bmatrix} \text{i} \\ \text{u} \\ \text{y} \end{Bmatrix}$

Note that the invariance condition continues to restrict the application of these rules. PI-6, for example, can apply only to plain stops (and vacuously to aspirated stops), since the tense stops are specified [-asp].

Most of the above analysis is forced by our assumptions and the facts of Korean. Since plain stops are contextually determined interpretations as aspirated (PI-6) and tense (PI-4), they must be underlyingly unspecified for these features as a consequence of the invariance condition. Since tense and aspirated obstruents are never voiced they are (redundantly) voiceless underlyingly because of the fact that we are assuming that interpretations are given as "early" as possible. It follows that only the plain stops can have voiced allophones. Recall that since aspirated and tensed stops must be specified for these features in the lexicon the structurally determined alternation with plain stops must be handled by an allomorphy rule. Since m and n never alternate they are fully interpreted for nasality at the syllable level, and hence only /n/ will undergo lateralization.

It is interesting to note that arguments internal to Korean lead us to set up the underlying contrasts in such a way as to keep the least marked segments unspecified for several features. The plain stops are the least marked obstruents. Presumably, n is the least marked nasal. It is of interest that in fast speech n is assimilated to following stops and nasals.

4. Conclusion and comparisons. We hope to have shown that the view of phonology sketched out in this paper is an interesting and viable alternative to standard generative phonology and to more recent developments in hierarchical phonology. Of course, a great deal more work and specification of loose ends must be done before we can reach any firm conclusions. In this section we want to draw some tentative conclusions and make some comparisons between our theory and some alternative ones.

If we compare our theory with structuralist views of phonemics, we can see that there are some similarities and some differences. The main similarity that we can see is that our theory makes a sharp distinction between two types of rules: essentially allophonic rules and what in structuralist phonology would be morphophonemic rules (our lexical redundancy

rules). However, we cut the pie in a rather different way and in addition give a principled interpretation to the two kinds of rules identifying the allophonic rules with rules of phonetic interpretation. The main difference is in the fact that we have no requirement of biuniqueness (in other words lexically different segments can have overlapping allophones).

There are a number of differences between our theory and various generative theories, some of which we've stressed already. One important difference comes out in a sharper picture of different kinds of neutralizations. One kind seems always to involve an alternation between a basic more marked segment and a predictable less marked segment. Such alternations seem to be structurally determined. The other kind, typically getting more marked segments from less-marked ones, seems to always involve assimilations to values of adjoining segments. The latter type of rule corresponds in part to the allophonic rules of structural phonemics (or in generative phonology 'low-level' phonetic rules) but includes neutralizations that could not be considered allophonic in most such theories.

To bring out more clearly just what the differences are between our theory and alternative theories it's necessary to cast them into some kind of common framework. The most general framework to do this is a generative framework (i.e. of various alternatives we know of the general classical theory is the least constrained). So we'll undertake the exercise of translating our theory into a theory with the following features:

1. Rules are distributed into three blocks, extrinsically ordered as blocks:

   (a) rules dealing with word formation and inflection:

   (b) rules which change marked feature specifications into unmarked ones; conditions on these rules are purely structural (e.g. they may refer to syllable structure, etc., but not to adjoining segments). The depth of ordering in these rules is exactly one.

   (c) rules which change unmarked to marked specification; these rules may refer to (immediate) contexts. The depth of ordering is indeterminate, but the only ordering is intrinsic (feeding).

2. There are no segments which are everywhere given a null value.

3. In particular, boundary symbols are excluded.

4. Changes in the value of a feature for a segment are restricted to just the following sequence in a derivation: marked-F $\longrightarrow$ unmarked-F $\longrightarrow$ marked-F (where the first step must come from rules of type (1b) or possibly of type (1a)).

5. Forms which show no alternation are specified completely as they are combined with other segments to form syllables, up to the specifications of rules of type (1c).

We have assumed that the value of a phonetic feature may never be reinterpreted in the course of a "derivation". This condition, which we have referred to as the invariance condition, is a fundamental property of the theory of phonology presented in this paper. We have discussed a number of interesting implications of adopting this condition. As a direct consequence of the invariance condition, it has been nec-ssary to assume that any features which undergo change in the course of a standard derivation are left unspecified in the phonemic representation. We have been able to make use of the fact that certain phonemes are only partially interpreted to eliminate extrinsic ordering for one set of morphophonemic rules in Korean. In addition, any alternation involving the change of a specified feature value must be viewed as a lexical redundancy rule. In general, the invariance condition has the effect of placing strong restrictions on the class of possible phonological analyses. We intend to pursue questions pertaining to markedness, rule ordering and properties of phonological rules in future research. We expect that this research will result in a highly constrained theory which only permits a very limited amount of abstractness in grammars.[8]

Footnotes

[1]Montague's three basic papers on the analysis of natural language are reprinted in Montague, 1974. Most transformational grammars can be reinterpreted as Montague grammars (although not of the restricted sort we assume here). See Cooper, 1975, Cooper and Parsons, 1976.

[2]We omit reference to the so-called meaning postulates, which are restrictions on the set of possible interpretations.

[3]This statement is slightly misleading. Semantic rules are defined for (compositional) syntactic rules. In a sense the ordering is simultaneous.

[4]For example, Liberman and Prince, 1977; Kahn, 1976; Selkirk, 1980; Halle and Vergnaud, ms; this work represents in part a revival of earlier work on hierarchical phonology by Pike and Pike (1947) and Fudge (1969).

[5]We will have relatively little to say about the problems of choosing categorial assignments here. In the area of syntax, choice is based on a variety of considerations, including semantic ones. In general, functions cannot exist independently of their arguments, but argument categories can exist independently of functions. Keenen's functional principles (Keenan, 1974) states that the form and interpretation of a function depends on the form and interpretation of its arguments. We would expect that phonetic considerations will play a similar role in narrowing down the choice here. For more discussion, see Wheeler, 1981, Bach, 1981.

[6]Lee (1976:101) formulates a rule of cluster simplification, but

alongside pairs like palp-pap we find pairs like ccalp-ccal (Park, 1977:51)

[7]Fortunately, there have been a number of excellent studies of Korean phonology from a wide variety of viewpoints. We have drawn especially on Kim, 1976 and Lee, 1976.

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