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FUNCTIONAL OPTIMALITY THEORY

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Abstract

This paper briefly introduces Optimality Theory from the functionalist viewpoint.

1. Introduction

The functional hypothesis for phonology (Passy 1890) maintains that sound structures reflect an interaction between the articulatory and perceptual principles of efficient and effective communication. The theory of Functional Phonology (Boersma 1997a) maintains that this interaction is directly reflected in the grammar: it handles substance-related phonological phenomena within the constraint-ranking framework introduced by Optimality Theory (Prince & Smolensky 1993), but without the need for positing innate features and hierarchies; if restricted to gestural and faithfulness constraints, its scope equals that of autosegmental phonology and feature geometry.

2. Grammar model

Functional Phonology makes a principled distinction between articulatory and perceptual representations and features. Figure 1 shows its concept of the grammatical correlates of the systems, processes, and representations of the speech production and perception systems of a single speaker-listener:

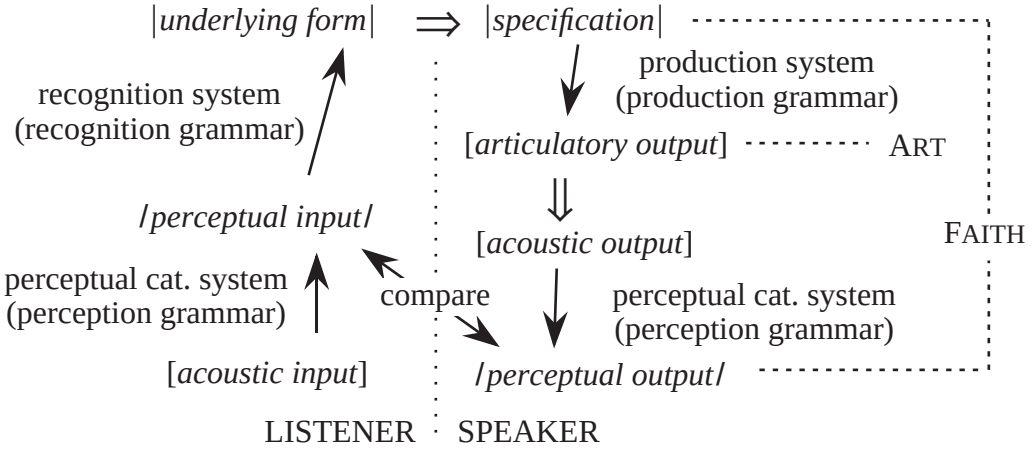


Figure 1: the grammar model of Functional Phonology.

In figure 1, we see the following representations:

(1) The *acoustic input* of the speech uttered by another person, as presented to the ear of the listener; written between brackets because it is a language-independent representation.
(2) The *perceptual input*: the speech uttered by another person, as perceived by the listener, in terms of perceptual features (periodicity, noise, spectrum) and their combinations; written between slashes.
(3) A *perceptual specification* in terms of perceptual features, as stored in the language user's lexicon; written between pipes.
(4) The *articulatory output* of the speaker, in terms of articulatory gestures (articulator positions, muscle tensions) and their combinations; written between brackets.
(5) The *acoustic output* of the speaker: an automatic result of her articulatory output; also written between brackets.
(6) The *perceptual output* of the speaker: her acoustic output, as perceived by herself; written between slashes.

Figure 1 also shows the following processing systems:

- The speaker's *production system* determines the surface form of the utterance from an underlying perceptual specification.
- The listener's *perceptual categorization system* determines how a listener converts the raw acoustic input to a more perceptual representation; she uses the system for the acoustic input from other speakers as well as for her own acoustic output.
- The listener's *recognition system* converts the perceptual input into an underlying form (and helps the categorization system).
- A *comparison module* on behalf of language acquisition. If the learner's output, as perceived by herself, differs from the adult utterance, as perceived by the learner, the learner will take a learning step (Boersma, to appear; Boersma 1997b).

The abbreviations ART and FAITH refer to *articulatory* and *faithfulness* constraints, as explained below.

3. Constraint-ranking grammars and functionalism

Consider the process of place assimilation of nasals in Dutch. The words /tʀɛin/ 'train' and /pɑkə/ 'catch' will often be concatenated as /tʀɛimpɑkə/. The process is confined to the coronal nasal: bilabial nasals, velar nasals, and plosives at any place, do not usually assimilate.

3.1. Explanation versus description

A phonetic explanation for these facts can readily be given: as compared to the articulation [tʀɛinpɑkə], the articulation [tʀɛimpɑkə] saves the speaker one tongue-tip gesture, since the bilabial gesture for [m] was already needed for [p]; the perceptual loss of this assimilation is the neutralization of any specified |n| and |m|, which could lead to confusions between words that end in these sounds, and to extra required effort in the recognition system. The restriction to nasals can be explained by the fact that e.g. the nasals /m/ and /n/ are perceptually much more alike than the plosives /p/ and /t/, so that the listener will rely less on place information for nasals than for plosives, so that the speaker has more freedom to mispronounce a nasal than

a plosive; the restriction to coronals can be explained by the fact that coronals are much more common than labials, so that the listener will have a bias towards recognizing a coronal instead of a labial, so that the speaker will assume that the listener will reconstruct the coronal even if she pronounces it as a labial.

These explanations, however, do not tell us what a speaker does when she has to concatenate the words /tʀɛin/ and /pɑkə/, and this is why phonetic explanations have seldom met with enthusiasm on the part of linguists.

Until 1993, linguists tended to describe phonological processes with *rules*, e.g., they would describe nasal place assimilation with a structure-changing recipe like "n → m / _ p", or with a generalization over the various places, or with a feature-filling recipe like "[0place] → [αplace] / _ [αplace]", or in an autosegmental and/or feature-geometric formulation. All these notational variants, however, are still recipes and have little explanatory power. So the explanatory and descriptive accounts had been divorced for a long time.

3.2. Constraint-ranking grammars

The advent of Optimality Theory (Prince & Smolensky 1993; McCarthy & Prince 1993a, 1993b, 1994, 1995) changed this situation, by making *constraints* instead of rules central to the grammar. A traditional Optimality-Theoretic account of nasal place assimilation would have that a universal constraint NASSIM ("nasals have the same place as a following consonant") is *dominating* the universal constraint IDENT (place) ("the surface place is equal to the underlying place specification"). Since these constraints are *violable*, the outcome depends on their *rankings*, so that we have the following mini-typology: if NASSIM outranks IDENT (place), there will be assimilation; if, on the other hand, IDENT (place) >> NASSIM, there won't.

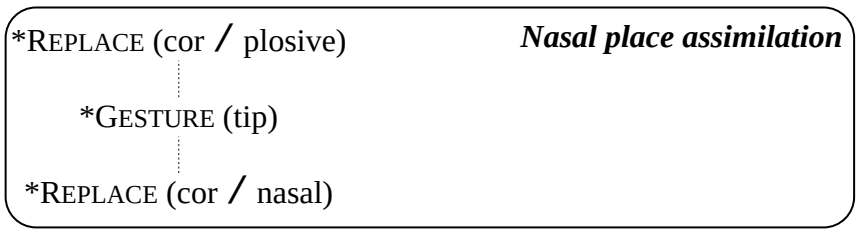
A constraint like NASSIM still provides no explanation: it is still purely descriptive. But instead of these allegedly universal constraints, we can directly translate the phonetic principles of minimization of effort and perceptual confusion into the grammar, namely, into *articulatory constraints* ("ART" in figure 1), which evaluate articulatory outputs, and *faithfulness constraints* ("FAITH" in figure 1), which evaluate the similarity between the specification and the perceptual output.

For nasal place assimilation, the relevant articulatory and faithfulness constraints would be

*GESTURE (tongue tip: close & open):
"do not make a tongue-tip opening and closing gesture"

*REPLACE (place: coronal, labial / nasal / _ C):
"do not implement a perceptual coronal place specification as something that will be heard as labial place, for a nasal, before a consonant"

The Dutch assimilation process can then be seen as the result of the following grammar of ranked constraints (I will freely abbreviate constraint names):



(2)

Because plosives do not assimilate, the constraint *REPLACE (place: coronal, labial / plosive / _ C) must be ranked higher than *GESTURE (tongue tip). Note that the ranking of *REPLACE (place / plosive) above *REPLACE (place / nasal) reflects the asymmetry of perceptual confusion discussed above, so that we may well hypothesize that this ranking is nearly universal. Indeed, if we could find out what rankings are universal and what rankings can be set on a language-specific basis, we would have a typologically adequate account of possible and impossible sound systems, which, in my view, is an important goal of phonological theory.

Thus, violable constraints can be expressed in such a general way that they yield to the linguist's requirement of universality and simplicity, and to the phonetician's requirement of explicability in terms of the properties of the human speech mechanism. In Boersma (forthcoming), I identify these functional constraints, investigate their interactions, and show their empirical adequacy.

4. The production grammar

So I will assume that the speaker's production system can be described by an Optimality-Theoretic production grammar.

A typical production process can thus be represented with the following Optimality-Theoretic *tableau*:

$\lvert spec \rvert$	A	B
☞ [art_1] /$perc_1$/		*
[art_2] /$perc_2$/	*!	

(3)

This tableau shows the following representations, each of which can be identified in figure 1:

(1) A perceptual specification *spec*.
(2) Many candidate articulatory outputs art_i.
(3) For each candidate articulatory output art_i: the corresponding perceptual output $perc_i$.

In tableau (3), the two constraints A and B both issue a *protest* against a certain candidate, as shown by the asterisks (the *marks*). Because A is ranked higher than B, the *disharmony* associated with its violation is greater than that of B, and its violation becomes the *crucial violation* for candidate 2, as shown by the exclamation symbol, which is put after the *crucial mark*. Thus, candidate 1 is more *harmonic* (less offensive) than 2, so it becomes the *winner*, as shown by the pointing finger. Some cells are grey because any violations in these cells have not contributed to determining the winner.

Our example of nasal place assimilation is written as

|an+pa|	*GESTURE (tip)	*REPLACE (cor)
[anpa] /anpa/	*!	
☞ [ampa] /ampa/		*

(4)

The candidate [ampa] (shorthand for "pharyngeal narrowing plus lip closure and opening plus velum raising..."), which is perceived as /ampa/ (shorthand for "high F_1 plus labial place plus nasality..."), is the winner.

The fact that phonetic principles can be expressed in an Optimality-Theoretic grammar, was independently discovered by a research group in California (Jun 1995, Flemming 1995, Hayes 1996, Kirchner 1998). The differences between their theories and the view of functional phonology described here, are discussed in Boersma (forthcoming).

5. The perception grammar

I will likewise assume that the listener's categorization system can be described by an Optimality-Theoretic *perception grammar*.

We can thus represent a typical categorization process with the following tableau:

[*ac*]	A	B
☞ /cat_1/		*
/cat_2/	*!	

(5)

This tableau shows the following representations (visible twice in figure 1):

(1) An acoustic input *ac*.
(2) Several candidate perceptual categories cat_i.

For instance, on the perceptual tier F_1 (first formant), the listener may have three categories of 300, 500, and 700 Hz (for high, mid, and low vowels, respectively). If the acoustic input is 440 Hz, a relevant constraint is:

*WARP (F_1: [440], /300/):
"do not initially classify an acoustic input of 440 Hz as a high vowel"

The decision of the categorization system can now be described with the following tableau, if the system is trying to initially classify any acoustic input into the "nearest" category:

[440]	*WARP ([440], /700/)	*WARP ([440], /300/)	*WARP ([440], /500/)
/300/		*!	
☞ /500/			*
/700/	*!		

(6)

The winner is the category /500/, i.e., the input of 440 Hz is initially perceived as a mid vowel (the recognition system may correct this initial categorization on the basis of other information).

6. Conclusion

The hypothesis of Functional Phonology is that the production and categorization systems can be described with Optimality-Theoretic constraint-ranking grammars that contain direct translations of principles of minimization of articulatory effort and perceptual confusion.

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