Articulatory Features

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Phonological come in various flavors:

(1) Contrastive, relating to minimal distinctions between morphemes.
   a. *mace* /mejs/ vs. *maze* /mejz/
   b. *thy* /ðaj/ vs. *thigh* /θaj/

(2) Allomorphic, relating to different realizations of the same morpheme.
   a. *cap-s* /kæp-s/ vs. *cab-s* /kæb-z/
   b. *dog-s* /dɑg-z/ vs. *dock-s* /dɑg-z/

(3) Phonotactic, relating to the distribution of phonemes within a morpheme, word, or phrases
   a. In Standard German, voiced plosives cannot occur at the end of words.

(4) Prosodic, relating to the higher-order structure of words and phrases (e.g, syllables, stress, tone, intonation)
   a. In English, syllables must include a vowel, nasal, or approximant as their nucleus
   b. In English, aspirated plosives can only appear at the beginning of words and at the beginning of stressed syllables

All of these patterns relate, in one way or another, to classes of sounds that have a dual structure:

- They share something in common phonetically
- They share something in common functionally (they serve the same role in an allomorphic, phonotactic, or prosodic pattern)

Sometimes, these classes are said to have a third aspect, namely a cognitive representation. Together, these associations are called phonological features. The structure of a feature, according to the mainstream position is shown in Figure 1. If a set of phonological features are named according to their articulatory properties, they are called articulatory features and if they are named according to their acoustic properties, they are called acoustic features.

In this lecture, we will explore articulatory features.

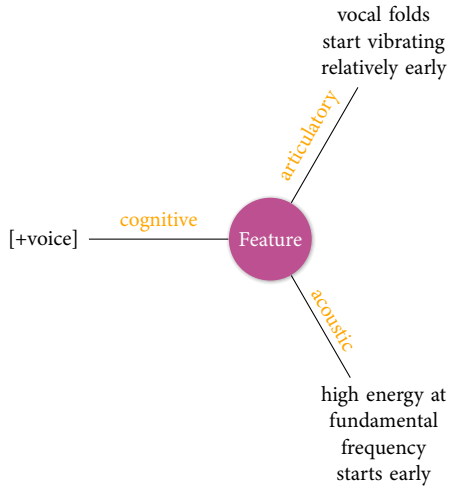

Figure 1: The tripartite structure of a phonological feature.

Articulatory Feature Representations

In the seminal *Sound Pattern of English*, sounds were represented as vectors of articulatory features. These features could be + (active), − (inactive), or 0 (unspecified, meaning that it is not relevant, given the other values in the vector). Some examples of feature vectors are given in Table 1.

ipa	syl	son	cons	cont	delrel	lat	nas	strid	voi	sg	cg	ant	cor	distr	lab	hi	lo	back	round	velaric	tense	long	hitone	hireg
c	−	−	+	−	−	−	−	0	−	−	−	−	−	0	−	+	−	−	−	−	0	−	0	0
ɡ	−	−	+	−	−	−	−	0	+	−	−	−	−	0	−	+	−	+	−	−	0	−	0	0
k	−	−	+	−	−	−	−	0	−	−	−	−	−	0	−	+	−	+	−	−	0	−	0	0
q	−	−	+	−	−	−	−	0	−	−	−	−	−	0	−	−	−	+	−	−	0	−	0	0
ɖ	−	−	+	−	−	−	−	0	+	−	−	−	+	−	−	−	−	−	−	−	0	−	0	0
ɟ	−	−	+	−	−	−	−	0	+	−	−	−	−	0	−	+	−	−	−	−	0	−	0	0
ɠ	−	−	+	−	−	−	−	0	+	−	+	−	−	0	−	+	−	+	−	−	0	−	0	0
ɢ	−	−	+	−	−	−	−	0	+	−	−	−	−	0	−	−	−	+	−	−	0	−	0	0
ʄ	−	−	+	−	−	−	−	0	+	−	+	−	−	0	−	+	−	−	−	−	0	−	0	0
ʈ	−	−	+	−	−	−	−	0	−	−	−	−	+	−	−	−	−	−	−	−	0	−	0	0
ɠ̊	−	−	+	−	−	−	−	0	+	−	+	−	−	0	−	−	−	+	−	−	0	−	0	0
b	−	−	+	−	−	−	−	0	+	−	−	+	−	0	+	−	−	−	−	−	0	−	0	0
d	−	−	+	−	−	−	−	0	+	−	−	+	+	−	−	−	−	−	−	−	0	−	0	0
d̪	−	−	+	−	−	−	−	0	+	−	−	+	+	+	−	−	−	−	−	−	0	−	0	0
p	−	−	+	−	−	−	−	0	−	−	−	+	−	0	+	−	−	−	−	−	0	−	0	0
ɱ	−	+	+	−	0	−	+	0	+	−	−	+	−	0	+	0	0	0	−	−	0	−	0	0
ŋ	−	+	+	−	−	−	+	0	+	−	−	−	−	0	−	+	−	+	−	−	0	−	0	0
ɳ	−	+	+	−	−	−	+	0	+	−	−	−	+	0	−	−	−	−	−	−	0	−	0	0
ɴ	−	+	+	−	−	−	+	0	+	−	−	−	−	0	−	−	−	+	−	−	0	−	0	0
m	−	+	+	−	−	−	+	0	+	−	−	+	−	0	+	−	−	−	−	−	0	−	0	0
n	−	+	+	−	−	−	+	0	+	−	−	+	+	−	−	−	−	−	−	−	0	−	0	0
n̪	−	+	+	−	−	−	+	0	+	−	−	+	+	+	−	−	−	−	−	−	0	−	0	0
ɲ	−	+	+	−	−	−	+	0	+	−	−	−	−	0	−	+	−	−	−	−	0	−	0	0

Table 1: Features of some phonemes according to PanPhon.

The idea, in phonological feature theory, is that every phoneme corresponds to a unique feature vector.

Each feature is supposed to correspond to two nature classes:

(5) a. The class of phonemes where the feature is "on" or active
b. The class of phonemes where the feature is "off" or inactive

Some Important Features

	+	−
[syllabic]	vowels, syllabic consonants	(non-syllabic) consonants, glides
[consonantal]	consonants	vowels, glides
[sonorant]	vowels, glides, other approximants, nasal stops	plosives, fricatives
[continuant]	vowels, glides, other approximants, fricatives	plosives, nasal stops
[voice]	voiced segments	voiceless segments
[high]	high vowels, palatal and velar consonants	mid and low vowels, other coso-nants
[back]	back and central vowels, velar and uvular consonants	front vowels, other consonants

Table 2: Some important articulatory features

Putting Features to Work

How are these feature vectors put to use? Let's look at an example using Catalan masculine and feminine adjectives (Table 3. Note that voiceless plosives (/p/, /t/, /k/)and fricatives (/s/, /ʃ/) (as well, as nasals, approximants and vowels) are allowed to occur at the ends of words. However, morphemes that ends in a voiced plosive ([+voice, −sonorant, −continuant]) are realized with a final voiceless plosive ([−voice, −sonorant, −continuant]) when they occur word-finally, as with underlying /grog/ 'yellow' that surfaces as [grok] in the masculine singular. The same pattern affects fricatives, as is illustrated by /griz/ 'gray'. Therefore, the rule must really affect all [+voice, −sonorant] sounds. Thus, we may say (informally) that [−sonorant] sounds become [−voice] at the ends of words.

(2) $\left[-\text{son}\right] \rightarrow \left[-\text{voi}\right] \; / \; \_\_\#$

Note, though, that other alternations produce allomorphy in the data. For example, voiced plosives ([+voice, −sonorant, −continuant]) are realized as voiced fricatives ([+voice, −sonorant, +continuant]) in certain environments (between vowels/approximants and vowels). As shown by /fəkundə/, this rule does not apply between nasal stops and vowels. The rule, then, is that [+voice, −sonorant] become [+continuant] between [+sonorant, −nasal] and [+syllabic].

(3) $\begin{bmatrix}+\text{voi}\\-\text{son}\end{bmatrix} \rightarrow \begin{bmatrix}+\text{cont}\end{bmatrix} \;/\; \begin{bmatrix}+\text{son}\\-\text{nas}\end{bmatrix} \_\_ \begin{bmatrix}+\text{syl}\end{bmatrix}$

Extracting Articulator Features

There are software tools for extracting articulatory features from strings of phonemes. Probably the most widely used of these is PanPhon.[1] You can find documentation for PanPhon at `https://github.com/dmort27/panphon`.

This is how you can use Panphon to extract the features from a very short word:

```
>>> import panphon
>>> ft = panphon.FeatureTable()
>>> ft.word_fts('p')
[<Segment [-syl, -son, +cons, -cont, -delrel, -lat, -nas,
 0strid, -voi, -sg, -cg, +ant, -cor, 0distr, +lab, -hi, -lo,
 -back, -round, -velaric, 0tense, -long, 0hitone, 0hireg]>]
>>>
```

PanPhon defines a number of set operations over feature vectors:

```
>>> from panphon.segment import Segment
>>> a = Segment(['syl', 'son', 'cont'], {'syl': -1,
 'son': -1, 'cont': 1})
>>> a.match({'son': -1, 'cont': 1})
True
>>> a.match({'son': -1, 'cont': -1})
False
>>> a >= {'son': -1, 'cont': 1}
True
>>> a >= {'son': 1, 'cont': 1}
False
```

For the exercise, the most useful of these is probably `intersection`:

```
>>> a = Segment(['syl', 'son', 'cont'], {'syl': -1,
 'son': -1, 'cont': 1})
>>> a.intersection({'syl': -1, 'son': 1, 'cont': -1})
<Segment [-syl]>
>>> a & {'syl': -1, 'son': 1, 'cont': -1}
<Segment [-syl]>
```

You can get vector representations out of a `Segment` object using the `numeric` and `strings` methods:

```
>>> a = Segment(['syl', 'son', 'cont'], {'syl': -1,
 'son': -1, 'cont': 1})
```

[1] David R. Mortensen, Patrick Littell, Akash Bharadwaj, Kartik Goyal, Chris Dyer, and Lori Levin. PanPhon: A resource for mapping IPA segments to articulatory feature vectors. In Yuji Matsumoto and Rashmi Prasad, editors, *Proceedings of COLING 2016, the 26th International Conference on Computational Linguistics: Technical Papers*, pages 3475–3484, Osaka, Japan, December 2016. The COLING 2016 Organizing Committee. URL `https://aclanthology.org/C16-1328`

```
>>> a.numeric()
[-1, -1, 1]
>>> a.strings()
['-', '-', '+']
```

Other sets of articulatory features exist. The best and most extensive of these is part of PHOIBLE (`https://phoible.org/`)[2], a cross-linguistic database of phones.

[2] Steven Moran and Daniel McCloy, editors. *PHOIBLE 2.0*. Max Planck Institute for the Science of Human History, Jena, 2019. URL `https://phoible.org/`

Exercises

- **Identify the other alternations (patterns of allomorphy) in the Catalan data** and describe them in terms of naturual classes.
- **Write rules for each of he alternations in the Catalan data** using articulatory features. You can consult PanPhon for determining the features.
-

References

Steven Moran and Daniel McCloy, editors. *PHOIBLE 2.0*. Max Planck Institute for the Science of Human History, Jena, 2019. URL `https://phoible.org/`.

David R. Mortensen, Patrick Littell, Akash Bharadwaj, Kartik Goyal, Chris Dyer, and Lori Levin. PanPhon: A resource for mapping IPA segments to articulatory feature vectors. In Yuji Matsumoto and Rashmi Prasad, editors, *Proceedings of COLING 2016, the 26th International Conference on Computational Linguistics: Technical Papers*, pages 3475–3484, Osaka, Japan, December 2016. The COLING 2016 Organizing Committee. URL `https://aclanthology.org/C16-1328`.

MASC SG	FEM SG		MASC SG	FEM SG	
əkelʲ	əkelʲə	‘that’	mal	malə	‘bad’
siβil	siβilə	‘civil’	əskerp	əskerpə	‘shy’
ʃop	ʃopə	‘drenched’	sɛk	sɛkə	‘dry’
əspɛs	əspɛsə	‘thick’	gros	grosə	‘large’
baʃ	baʃə	‘short’	koʃ	koʃə	‘lame’
tot	totə	‘all’	brut	brutə	‘dirty’
pɔk	pɔkə	‘little’	prəsis	prəsizə	‘precise’
frənses	frənsezə	‘French’	gris	grizə	‘grey’
kəzat	kəzaðə	‘married’	bwit	bwiðə	‘empty’
rɔt͡ʃ	rɔʒə	‘red’	bot͡ʃ	boʒə	‘crazy’
orp	orβə	‘blind’	lʲark	lʲarɣə	‘long’
sek	seɣə	‘blind’	fəʃuk	fəʃuɣə	‘heavy’
grok	groɣə	‘yellow’	puruk	puruɣə	‘fearful’
kandit	kandiðə	‘candid’	frɛt	frɛðə	‘cold’
səɣu	səɣurə	‘sure’	du	durə	‘hard’
səɣəðo	səɣəðorə	‘reaper’	kla	klarə	‘clear’
nu	nuə	‘nude’	kru	kruə	‘raw’
flɔɲd͡ʒu	flɔɲd͡ʒə	‘soft’	dropu	dropə	‘lazy’
əgzaktə	əgzaktə	‘exact’	əlβi	əlβinə	‘albino’
sa	sanə	‘healthy’	pla	planə	‘level’
bo	bonə	‘good’	sərɛ	sərɛnə	‘calm’
suβlim	suβlimə	‘sublime’	al	altə	‘tall’
fɔr	fɔrtə	‘strong’	kur	kurtə	‘short’
sor	sorðə	‘deaf’	bɛr	bɛrðə	‘green’
san	santə	‘saint’	kəlɛn	kəlɛntə	‘hot’
prufun	prufundə	‘deep’	fəkun	fəkundə	‘fertile’
dəsen	dəsentə	‘decent’	dulen	dulentə	‘bad’
əstuðian	əstuðiantə	‘student’	blaŋ	blaŋkə	‘white’

Table 3: Catalan adjectives