Carnegie Mellon University
Language
Technologies
Institute

11-324/11-624/11-724 Human Language for AI

Phonemes and Underlying Representations

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September 19, 2022

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Learning Objectives

At the end of this lecture students will know:

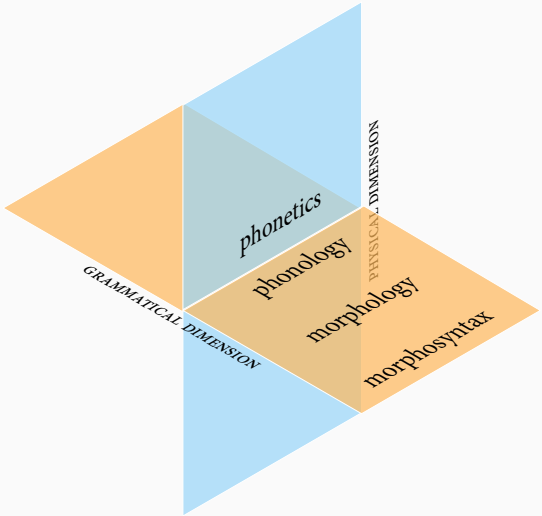
- How phonetic representations and different from phonological representations
- How phonetic and phonological representations relate to one another
- That phonological representations are a kind of normalization of other representations
- How phonemic representations are different from underlying representations

Students will be able to:

- Perform a phonemic analysis of data from an unfamiliar language
- Posit correct underlying representations for morphemes
- Be able to identify the correct ordering of two rules, given data

Phonetics and Phonology

Phonetics and phonology



Phonology as Normalization

Sound patterns

orthographic	phonetic
im-possible	[ɪm-pʰɑsəbl̩]
in-tolerable	[ɪn-tʰɑlərəbl̩]
in-conceivable	[ɪŋ-kʰənsivəbl̩]
il-legal	[ɪl-ligl̩]
ir-regular	[ɪɹ-ɹɛgjəl̩]

Allophones of English Plosives

aspirated	unreleased	unaspirated
pin	nip	spin
tick	kit	stick
kin	nick	skin

Allophony in Korean

kal	‘that’ll go’	ilkop	‘seven’	iɾɯni	‘name’
kɯnɯl	‘shade’	ipalsa	‘barber’	kiɾi	‘road’
mul	‘water’	onɯlpːam	‘tonight’	kɯɾəm	‘then’
pal	‘leg’	pulpʰjən	‘discomfort’	kəɾiɾo	‘to the street’
pʰal	‘arm’	silkwa	‘fruit’	saɾam	‘person’
səul	‘Seoul’	tɯlʧjaŋ	‘window’	uɾi	‘we’
tatɯl	‘all of them’	əlmana	‘how much’	yəɾɯm	‘summer’

Phonemes are contrasting units of sound.

Korean T-Charts

l	
a	#
ɯ	#
u	#
a	#
a	#
u	#
ɯ	#
i	k
a	s
ɯ	p:
u	p^h
i	k
ɯ	t͡ʃ
ə	m

r	
i	ɯ
ɯ	ə
ə	i
a	a
u	i
ə	ɯ

Tusom Fricatives

Are [h] and [f] in contrast or are they allophones of one phoneme?

Form	Gloss
ʔametχahitəpʰepʰeʔe	banana is soft
ɹãmfɯ	fox
kʰãfɯ	steal (v.)
kəfɯ	put (v.)
hakət͡sɯ	sneeze
ʔɯkfukət͡ɕʰy	wash hands (v.)
mápfy̆t͡sɯ	tear (n.)
kfɯ	village/state
mehe	leech
məkuhẽ	twenty
kfɯnt͡sɯ	fingernail

Ordering

We will view allophonic rules as being INTRINSICALLY ORDERED. This means that the order in which the rules apply is governed by how specific the environment in the rule is (from most specific to most general). There is always an "elsewhere" rule that gives the realization of the phoneme if none of the more specific rules applies.

- Korean
  1. /l/ → [ɾ] / V_V (between vowels)
  2. /l/ → [l] / elsewhere
- American English
  1. /t/ → [tʰ] / at the beginning of stressed syllables
  2. /t/ → [t̚] / _# (word-finally)
  3. /t/ → [t] / elsewhere

Different Forms of the Same Morpheme

Singular	Phonemic	Plural	Phonemic
dog	/dɑg/	dogs	/dɑg-z/
cat	/kæt/	cats	/kæt-s/
horse	/hɔɹs/	horses	/hɔɹs-əz/

Different Forms of the Same Morpheme

Infinitive	Phonemic	3SG	Phonemic
take	/tejk/	takes	/tejk-s/
give	/gɪv/	gives	/gɪv-z/
watch	/wɑt͡ʃ/	watches	/wɑt͡ʃ-əz/

Active	Passive	Gerund	Gloss
hopu	hopukia	hopukaŋa	‘catch’
aru	arumia	arumaŋa	‘follow’
tohu	tohuŋia	tohuŋaŋa	‘point out’
maatu	maaturia	maaturaŋa	‘know’

ACTIVE — I *catch* the fish.

PASSIVE — The fish *is caught*.

GERUND — Her *catching* the fish was good.

Active	Passive	Gerund	Gloss
hopu	hopuk-ia	hopuk-aŋa	‘catch’
aru	arum-ia	arum-aŋa	‘follow’
tohu	tohuŋ-ia	tohuŋ-aŋa	‘point out’
maatu	maatur-ia	maatur-aŋa	‘know’

Phonology as a Computational System

Maori II

UR of Root	Active	Passive	Gerund	Gloss
/hopuk/	hopu	hopuk-ia	hopuk-aŋa	‘to catch’
/arum/	aru	arum-ia	arum-aŋa	‘to follow’
/tohuŋ/	tohu	tohuŋ-ia	tohuŋ-aŋa	‘to point out’
/maatur/	maatu	maatur-ia	maatur-aŋa	‘to know’

Phonemic Representations Versus Underlying Representations

Phonemic representations and underlying representations both represent normalizations over the sounds of speech. They are both enclosed in slashes. However, they are not the same.

Phonemic Representations	Underlying Representations
Phonemes	Underlying segments
Normalization over **phones**	Normalization over **allomorphs**
Each **phoneme** always has the same representation	Each **morpheme** always has the same representation

$$\left\{\begin{array}{c} p \\ t \\ k \\ m \\ n \\ ŋ \\ r \\ \dots \end{array}\right\} \rightarrow 0 \ / \ \_ \ \#$$

Voicing Assimilation

$$z \rightarrow s \; / \left\{ \begin{array}{c} p \\ t \\ k \\ f \\ \theta \\ s \\ \int \\ \widehat{t\int} \end{array} \right\} \_ \; \#$$

Schwa Epenthesis

$$0 \rightarrow \text{ə} \; / \; \left\{ \begin{matrix} \text{s} \\ \text{z} \\ \text{ʃ} \\ \text{ʒ} \\ \text{t͡ʃ} \\ \text{d͡ʒ} \end{matrix} \right\} \; \_ \; \left\{ \begin{matrix} \text{s} \\ \text{z} \\ \text{ʃ} \\ \text{ʒ} \\ \text{t͡ʃ} \\ \text{d͡ʒ} \end{matrix} \right\}$$

How Are They Ordered?

- Voicing assimilation

$$z \rightarrow s \; / \; \left\{ \begin{matrix} p \\ t \\ k \\ f \\ \theta \\ s \\ \int \\ \widehat{tʃ} \end{matrix} \right\} \_ \; \#$$

- Epenthesis

$$0 \rightarrow ə \; / \; \left\{ \begin{matrix} s \\ z \\ \int \\ ʒ \\ \widehat{tʃ} \\ \widehat{dʒ} \end{matrix} \right\} \_ \left\{ \begin{matrix} s \\ z \\ \int \\ ʒ \\ \widehat{tʃ} \\ \widehat{dʒ} \end{matrix} \right\}$$

Rule Interactions

feeding Rule A creates an environment where Rule B can apply

bleeding Rule A destroys and environment where Rule A would otherwise apply

counter-feeding Rule B would feed Rule A if their relative orders were reversed

counter-bleeding Rule B would bleed Rule A if their relative orders were reversed

Catalan Example I

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’
rɔʧ	rɔʒə	‘red’	boʧ	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’

Catalan Example II

MASC SG	FEM SG		MASC SG	FEM SG	
səɣu	səɣurə	‘sure’	du	durə	‘hard’
səɣəðo	səɣəðorə	‘reaper’	kla	klarə	‘clear’
nu	nuə	‘nude’	kru	kruə	‘raw’
flɔɲʤu	flɔɲʤə	‘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’