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# Week 0 – What is Phonology?

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## 1 Goals of cognitive science

- (1) Characterize the knowledge that humans possess in various cognitive domains (perception, categorization, language, reasoning, ...). [competence theory]

*... by a generative grammar I mean simply a system of rules that in some explicit and well-defined way assigns structural descriptions to sentences. Obviously, every speaker of language has mastered and internalized a generative grammar that expresses his knowledge of his language. This is not to say that he is aware of the rules of the grammar or even that he can become aware of them, or that his statements about his intuitive knowledge of the language are necessarily accurate ... Similarly, a theory of visual perception would attempt to account for what a person actually sees and the mechanisms that determine this rather than his statements about what he sees and why, though these statements may provide useful, in fact, compelling evidence for such a theory. (Chomsky 1965:8-9, Aspects)*

- (2) Discover the methods by which knowledge is acquired, including a characterization of innate restrictions on the form and acquisition of knowledge. [learning theory]

*A theory of linguistic structure that aims for explanatory adequacy incorporates an account of linguistic universals, and it attributes tacit knowledge of these universals to the child. It proposes, then, that the child approaches the data with the presumption that they are drawn from a language of a certain antecedently well-defined type, his problem being to determine which of the (humanly) possible languages is that of the community in which he is placed. Language learning would be impossible unless this were the case. The important question is: What are the initial assumptions concerning the nature of language that the child brings to language learning, and how detailed and specific is the innate schema (the general definition of “grammar”) that gradually becomes more explicit and differentiated as the child learns the language? For the present we cannot come at all close to making a hypothesis about innate schema that is rich, detailed, and specific enough*

*to account for the fact of language acquisition. Consequently, the main task of linguistic theory must be to develop an account of linguistic universals that, on the one hand, will not be falsified by the actual diversity of languages and, on the other, will be sufficiently rich and explicit to account for the rapidity and uniformity of language learning, and the remarkable complexity and range of the generative grammars that are the product of language learning. (Chomsky 1965, Aspects, 27; on explanatory adequacy see Chomsky 1965: 30-32, 34-37, ch 1, etc.)*

- (3) Understand how knowledge is applied in particular behaviors, and what limitations prevent performance from being coextensive with competence. [performance theory]

*There seems to be little reason to question the traditional view that investigation of performance will proceed only so far as understanding of underlying competence permits. . . . To my knowledge, the only concrete results that have been achieved and the only clear suggestions that have been put forth concerning the theory of performance, outside of phonetics, have come from studies of performance models that incorporate generative grammars of specific kinds . . . . (Chomsky 1965, Aspects, 10, in ch 1.2: Toward A Theory of Performance)*

## 2 What is Phonology?

- (4) Phonology refers to the two things: the study of sound patterns and the sound patterns themselves.
- (5) The study of phonology tries to answer the following questions:
- a. What are the sound patterns of the world's languages?
  - b. What are the principles underlying these patterns?
  - c. What are possible sound patterns?
  - d. How can we characterize the knowledge speakers have about the sound patterns of their language?
  - e. How do children learn the sound patterns of their language?
  - f. How do language phonologies change over time?
- (6) It is a striking fact that natural languages have sound patterns. Why should this be so?

### 2.1 Phonological Patterns

- (7) There are three kinds of patterns: phonotactics, alternations, and contrasts.

### 2.1.1 Phonotactics

- (8) Phonotactic patterns refer to the possible words in a language. See Chomsky and Halle (1965), Halle (1978).
- (9) English speakers could name new things (objects or actions) with words on the left, but not with the words on the right.

flump	flunp
blick	bnick
bist	bizt
slem	srem

★ If you are a native English speaker, do you agree with the statement in (9)?

- (10) It is striking that many English native speakers agree with the statement in (9) even though they have zero experience with *all* of those words.

★ Can you think of some more possible words of English and some more impossible words of English?

- (11) Assuming agreement among the native English speakers, how did they learn to discriminate words they never heard before in the same way?

- (12) Navajo (Sapir and Hojier 1967).

Possible Navajo Words		Impossible Navajo Words
ʃi:te:ʒ	‘we (dual) are lying’	ʃi:te:z
dasdo:lis	‘he (4th) has his foot raised’	dasdo:liʃ
sokos	(hypothetical)	sokoʃ
ʃokoʃ	(hypothetical)	ʃokos
ki:te:p	(hypothetical)	
pi:te:k	(hypothetical)	

Note [ʃ] is like *sh* in *shoe* and [ʒ] is like *ge* in *beige*.

★ Why do you think the words in the right column are not possible words in Navajo?

- (13) Note the binary distinction between “possible” and “impossible” word is a convenient abstraction (Albright and Hayes 2003).

kip > θwi:ks > bzarʃk

### 2.1.2 Alternations

(14) Alternations are patterns that occur when the same morpheme (=smallest string with a particular meaning) appears different in different contexts.

(15) English plural.

cat	k <sup>h</sup> æt	k <sup>h</sup> ætʰs
sack	sæk	sækʰs
dog	dɑg	dɑgʒ
grub	gɹʌb	gɹʌbʒ
dish	dɪʃ	dɪʃəʒ
fudge	fʌdʒ	fʌdʒəʒ
pea	p <sup>h</sup> i	p <sup>h</sup> iʒ
cow	k <sup>h</sup> aʊ	k <sup>h</sup> aʊʒ
man	mæn	mɛn
foot	fʊt	fɪt
wife	wɑɪf	wɑɪvʒ
whiff	wɪf	wɪfs

...

(16) Ignoring irregular forms like *men* and *feet*, can you predict which form of the regular suffix *-s*, *-z*, *-əz* goes on the following made-up words:

1. lɛp

2. rɑg

3. nɪʒ

(17) There is a big debate whether these forms are determined by analogy to existing forms or by rule (See Albright and Hayes (2003) for details).

(18) Consider the form of the adjectival suffix below from Georgian (Aronson 1982):

phizik-uri	‘physical’
kimi-uri	‘chemical’
akti-uri	‘active’
phrang-uli	‘French’
german-uli	‘German’
reakti-uli	‘reactive’
real-uri	‘real’
terminal-uri	‘terminal’

★ What form of the suffix do you think would go on to a hypothetical words like

1. misato

2. pita

3. badurpi
4. ramuto
5. ralako

(19) How did English and Georgian speakers learn these patterns?

### 2.1.3 Contrasts

(20) Languages differ in what makes up their underlying inventory of sounds (the **phonemes**). ■

(21) Handwriting as a metaphor (idea originates with Andy Wedel)

- a. “A” and “B” represent distinct categories
- b. Each letter has a set of major variants: majuscule/minuscule, printed/cursive
- c. Which major variant is used depends on linguistic context (e.g., beginning of sentence, beginning of proper name take majuscule) and social context (filling out a government form with printed letters vs. writing a personal letter in cursive)
- d. Each major variant has infinitely many minor variants, conditioned by surrounding letters, speed/carefulness of writing, individual handwriting habits, health/mood of the writer, and random fluctuations.
- e. The difference between “major” and “minor” is not sharp.
- f. The “same” letter may tend to have different realizations in different countries/regions

(22) Sounds have similar properties!

/p/ and /b/ represent distinct categories—called phonemes—in many languages, including English

- a. Each phoneme has some major variants, called allophones
  - (i) English: /p/ → [p], [p<sup>h</sup>]
- b. Which allophone to use can depend on linguistic context
  - (i) English: /p/ → [p<sup>h</sup>] at the beginning of a word or beginning of a stressed syllable ([ph]otáto, a[p<sup>h</sup>]ártment), and otherwise [p] (s[p]úttér, ú[p]ér)<sup>1</sup> (Acute accent [ˈ] indicates main stress)
- c. Which allophone to use can also depend on extralinguistic context.
  - (i) London English: /t/ → [t] or [ʔ] at the beginning of an unstressed, non-word-initial syllable: bu[t]ér or bu[ʔ]ér. The choice can depend on social context.
- d. Each major allophone also has infinitely many minor variants.

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<sup>1</sup>There are some complications we are ignoring.

- (i) conditioned by surrounding sounds: English [p] (and [p<sup>h</sup>]) can be realized with the lower lip touching the upper teeth instead of the upper lip if followed by an [f], as in Zipfian.
  - (ii) conditioned by speech rate/carefulness: In rapid speech, English [p] (and [p<sup>h</sup>]) may have lips closed for less time or not at all.
  - (iii) conditioned by individual speech habits: Some people are more likely than others to close their lips all the way for [p]
  - (iv) due to health/mood of the speaker: “scratchy” voice from inflamed larynx, loudness affected by mood...
  - (v) due to random fluctuations: how long lips are closed, how long and loud the puff of air (h) is in [p<sup>h</sup>]
- e. The difference between major and minor variants is not sharp: should the “labiodental” /p/ that can occur in [Zipfian] be considered a major allophone of /p/?
- f. The “same” phoneme can have different typical realizations in different languages, dialects
- (i) Word-initially, French /b/ has more vocal-fold vibration than English /b/.
- (23) Example from Mbabaram<sup>2</sup>. (Dixon 1991; language from Australia with one speaker left at the time of Dixon’s research.)

pir	‘emu’		
aba	‘body’		
alba	‘camp’		
nap	‘who’		
palán	‘moon’		
púmba	‘ashes’		
ɲíp	‘what’	ɲíb-ug	‘for what reason’
mberp	‘wild dingo’	mberb-ul	‘wild dingo-erg.’
tulbu	‘matches’		
tum	‘hard’		
kúludún	‘dove’		
adil	‘ring-tail possum’		
arək	‘magpie’	arəg-uŋg <sup>ə</sup>	‘magpie-erg.’
kuŋgak	‘kookaburra’	kuŋgag-ul	‘kookaburra-erg.’
kaɾúk	‘bandicoot’	kaɾúg-uŋ	‘bandicoot’s’

- ★ Do you think [p] and [b] represent different phonemes or are allophones of the same phoneme in Mbabaram? If they’re allophones of the same phoneme, in what contexts does each allophone appear?

- ★ How about [t] and [d]? [k] and [g]?

<sup>2</sup>The data are simplified! See the original for a fuller description of voicing

### 2.1.4 Cross-linguistic patterns

- (24) There are interesting patterns cross-linguistically as well. Most of these are tendencies.
- If a language has phonemes {b,d,g}, it tends to have {p,t,k}.
  - The word-initial triple consonant clusters a language allows is a subset of the double consonant clusters it allows (Greenberg 1978).
    - Example: In English, every initial triple consonant cluster (like *str*) is decomposable into clusters of length two; in this case, *st* and *tr*. Note not all initial clusters of length two which are combinable form legal initial triple clusters. I.e. \**stwek*, though *st* and *tw* are OK.
  - If a language palatalizes consonants before [e], they also do before [i] but not vice versa (and people generalize in this fashion when given undetermined stimuli!) (Wilson 2006).

## 2.2 Phonological Theory

- (25) Chomsky and Halle (1965) give three kinds of grammars.
- A grammar that accounts for the observed data is an **observationally adequate grammar**.
  - A grammar that not only is observationally adequate, but also gives the same treatment to novel utterances that a real speaker of the target language gives is a **descriptively adequate grammar**.
  - A theory that, when given a typical set of *learning data*, returns a grammar that is descriptively adequate, is an **explanatorily adequate theory**.

### 2.2.1 Observationally Adequate Grammars

- (26) Examples of an observationally adequate grammar for English noun plurals

I. (just list every word you know)

kɪæt	kɪæts	p <sup>h</sup> i	p <sup>h</sup> iz
sæk	sæks	k <sup>h</sup> aʌ	k <sup>h</sup> aʌz
d <sup>h</sup> ɑg	d <sup>h</sup> ɑgz	mæn	mɛn
gɪʌb	gɪʌbz	fʌt	fɪt
dɪʃ	dɪʃɪz	wʌɪf	wʌɪvz
fʌdʒ	fʌdʒɪz	wɪf	wɪfs
...			

I.e. when “asked” what the plural of some word is, the grammar just checks the list above.

★ What’s wrong with this list-view of grammar?

II. Add -s to everything, except for these exceptions:

d <sup>h</sup> ag	d <sup>h</sup> agz		k <sup>h</sup> aΛ	k <sup>h</sup> aΛz
gɪΛb	gɪΛbz		mæn	mɛn
dɪf	dɪfəz		fʊt	fɪt
fΛdʒ	fΛdʒəz		waɪf	waɪvz
...				

III. Add *-z* to everything, except for these exceptions:

kæt	kæts
sæk	sæks
mæn	mɛn
fʊt	fɪt
...	

IV. Add *-əz* after “sibilant” sounds, *-s* after non-sibilant [-voice] sounds, and *-z* otherwise, except for these exceptions:

mæn	mɛn
fʊt	fɪt
waɪf	waɪvz
...	

V. Change final /f/ to [v], and then add *-əz* after “sibilant” sounds, *-s* after non-sibilant [-voice] sounds, and *-z* otherwise, except for these exceptions:

mæn	mɛn
fʊt	fɪt
wɪf	wɪvz
...	

### 2.2.2 Descriptive adequacy

(27) The idea is that a descriptively adequate grammar captures the generalisations that real learners extract from the learning data—I think it makes the most conceptual sense to operationalize this in terms of novel utterances. In a famous early study of children, Berko (1958) found that English-speaking adults (all highly educated, in her sample) consistently give the following plurals when presented with invented words (pp. 155-158):

wΛg	wΛgz		lΛn	lΛnz
gʌtʃ	gʌtʃəz		nɪz	nɪzəz
kæʒ	kæʒəz		kra	kraz
toɪ	toɪz		tæs	tæsəz

★ Which of the grammars above could be descriptively adequate, given these data?

★ The adults disagreed about this word—what might we conclude?

heaf:        hifs, hivz

### 2.2.3 Explanatory adequacy

- (28) Obviously this is very difficult, but it is the heart of the enterprise.
- (29) How do people generalize on the basis of their linguistic experience?
- (30) In my mind, this is the fundamental question in phonology today (Wilson 2006, Moreton 2008, Hayes and Wilson 2008, Heinz 2007, to appear). See also Chomsky (1957, 1965), Chomsky and Halle (1965, 1968).
- (31) Another way of thinking about it: Can we develop such an intimate understanding of natural language and natural language learning that we can program a robot to learn language the way children do?(?)

*... the term 'numerical simulation' makes many of us uncomfortable. It is easy to build models on computers and watch what they do, but it is often unjustified to claim that we've learned anything from such exercises. The fact that some computer code produces a pattern that looks like a snowflake, or a flower, or an earthquake doesn't necessarily tell us that the ingredients of the code have anything to do with the natural phenomenon it seems to depict.*

(Langer, James S. 1999. Computing in Physics: Are We Taking It Too Seriously? Or Not Seriously Enough? Physics Today, July 1999, p.12)

*It can be argued that getting a machine to perform intelligently is more important than understanding how it does so. If a magic procedure—say for learning—did in fact lead to the level of performance desired, despite our inability to understand the resulting computation, that would of course be a landmark accomplishment. But to expect this kind of breakthrough is [naive]. We now have enough disappointing experience to expect that any particular insight is going to take us a very small fraction of the way to the kind of truly intelligent mechanisms we seek. The only way to reasonably expect to make progress is by chaining together many such small steps. And the only way to chain together these steps is to understand at the end of each one where we are, how we got there, and why we got no further, so we can make an informed guess as to how to take the next small step. A 'magic' step is apt to be a last step; it is fine, as long as it takes you exactly where you want to go. (emphasis original)*

(Smolensky, Paul. 1986. Information Processing in Dynamical Systems: Foundations of Harmony Theory. In David E. Rumelhart, James L. McClelland, and the PDP Research Group, Parallel Distributed Processing, Vol. 1: Foundations. Cambridge, Mass.: MIT Press, p.220)

## 2.3 Dealing with theories

- (32) Theories as composite entities
- a. Every serious theory of phonology has many, many components.
    - (i) SPE: rule notation, ordering, morpheme structure rules, linking, exception features, ...
    - (ii) OT: richness of the base, universal constraints, strict domination, factorial typology; ...
  - b. Goal of theory evaluation is therefore very rarely wholesale endorsement or rejection.
  - c. Focus instead on separating ‘chaff’ from ‘wheat’—on identifying the components that lead to specific incorrect predictions, and on replacing them with better alternatives. Impossible without first understanding the individual components and their interactions.
- (33) Suspension of commitment and disbelief
- a. Do not commit fully to any particular theory, nor reject theories on general grounds.
  - b. Focus instead on working out the specific predictions of any given theory, looking for new connections among facts as well as internal contradictions and falsifications.

## 2.4 Course methodology

- (34) Course methodology (aka instructor’s biases)
- a. Develop awareness/knowledge of the empirical phenomena
  - b. Simplification and approximation
    - (i) Develop reasonably simple methods of analysis (e.g., small set of possible rules).
    - (ii) Main goal is understanding the techniques and their failings, not simulation of speakers.
    - (iii) Focus first on basic cases, then on more difficult problems with the aim of approximating the important qualitative aspects of a phenomenon.

## 3 Summary

- (35) Phonological patterns are sound patterns. We will focus mainly on alternations, phonotactics, and contrast.
- (36) Most of our theories discussed are descriptively adequate, though we keep in mind the ultimate aim of explanatory adequacy.

## References

- Albright, Adam and Bruce Hayes. 2003. Rules vs. Analogy in English Past Tenses: A Computational/Experimental Study. *Cognition* 90:119–161.
- Aronson, Howard. 1982. *Georgian, a reading grammar*. Slavica.
- Chomsky, Noam. 1957. *Syntactic Structures*. Mouton & Co., Printers, The Hague.
- Chomsky, Noam. 1965. *Aspects*. MIT Press.
- Chomsky, Noam and Morris Halle. 1965. Some controversial questions in phonological theory. *Journal of Linguistics* 1:97–138.
- Chomsky, Noam and Morris Halle. 1968. *The Sound Pattern of English*. Harper & Row.
- Greenberg, Joseph. 1978. Initial and Final Consonant Sequences. In *Universals of Human Language: Volume 2, Phonology*, edited by Joseph Greenberg. Stanford University Press, pages 243–279.
- Halle, Morris. 1978. Knowledge Unlearned and Untaught: What Speakers Know about the Sounds of Their Language. In *Linguistic Theory and Psychological Reality*. The MIT Press.
- Hayes, Bruce and Colin Wilson. 2008. A Maximum Entropy Model of Phonotactics and Phonotactic Learning. *Linguistic Inquiry* 39:379–440.
- Heinz, Jeffrey. 2007. The Inductive Learning of Phonotactic Patterns. Ph.D. thesis, University of California, Los Angeles.
- Heinz, Jeffrey. to appear. On the role of locality in learning stress patterns. *Phonology* .
- Moreton, Elliot. 2008. Analytic bias and phonological typology. *Phonology* 25(1):83–127.
- Sapir, Edward and Harry Hojier. 1967. The Phonology and Morphology of the Navaho Language. *University of California Publications* 50.
- Wilson, Colin. 2006. Learning Phonology With Substantive Bias: An Experimental and Computational Study of Velar Palatalization. *Cognitive Science* 30(5):945–982.