LING240: LANGUAGE AND MIND

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ABSTRACT

This set of notes summarizes the Fall 2021 iteration of LING240 at the University of Maryland. We have talked about phonetics, phonology, morphology, syntax, language acquisition, sign language, and arguments for universal grammar. The textbooks that we used are "Patterns in the Mind" by Ray Jackendoff and "Language Files" by the Department of Linguistics of the Ohio State University.

The structure of my notes is largely based on the lectures by the instructor Dr. Tonia Bleam. [1] However, note that this is not a transcript of the original lectures, but rather an opinionated summary, where I include my own interpretations. I also tend to elaborate more on topics that I'm personally interested in. Furthermore, as LING240 is an introductory course, some concepts are introduced in a simplified manner. I might revisit some of them in the future to give a more complete story. Anyway, please always feel free to email me if you find any errors.

1 FUNDAMENTAL IDEAS

We first introduce several fundamental ideas in linguistics, mostly centering around the nature of human language and general philosophies when approaching language experiments. They lay the ground for many future discussions.

- Productivity: Expressive variety of human language, the ability to generate infinite number of new sentences by compositions.
- Mental Grammar: The system of rules stored in the mind of a speaker that generates the sentences of that speaker's language. (This concept is rather abstract, in Leslie's words, "mental grammar is a giant oversimplification" for explaining human perception and production of language. But let's just stick with it for this course.)
- Prescriptive vs Descriptive approaches: Descriptivism studies how people really speak and describe patterns that exists in the data, thus including many variations. Prescriptism is the opposite idea that makes judgement on whether the grammar is correct or wrong based on some prescriptive rules. We generally use the descriptive approach in linguistics study.
- Performance may not perfectly mirror competence: The mental grammar of people is competence, the outputs they produce is performance.

2 PHONETICS

2.1 DEFINITION

Phonetics is the study of the physical properties of speech sounds.

Phonology is the study of the mental representation of speech sounds, such as how sounds combine together and rules that change pronunciation of sounds.

[1] I also want to thank our TA Leslie Li for the interesting discussion.

Manner of Articulation \ Place of Articulation		Bilabial		Labio-dental		Inter-dental		Alveolar		Post-Alveolar		Palatal		Velar		Glottal	
	Stop	p	b					t	d					k	ɡ	ʔ	
	Fricative			f	v	θ	ð	s	z	ʃ	ʒ					h	
	Affricate									ʧ	ʤ						
	Flap								ɾ								
	Nasal		m						n						ŋ		
	Lateral Liquid								l								
	Retroflex Liquid								ɹ								
	Glide	ʍ	w										j				

State of the Glottis: Voiceless | Voiced

Figure 1: The consonants in English.

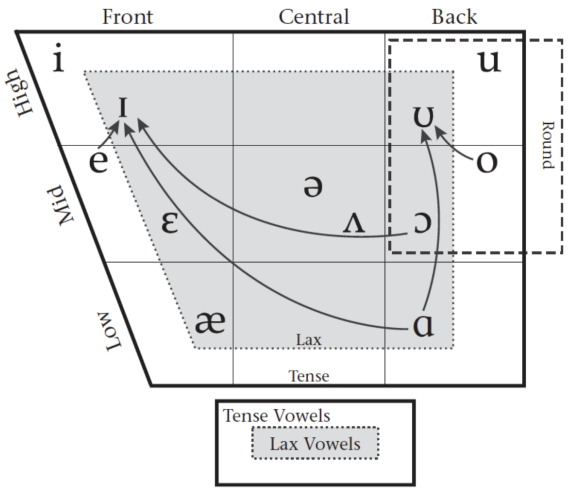

Figure 2: The vowels in English.

2.2 Consonants and Vowels

There are 2 classes of speech sounds: 1) **Consonants** are produced via obstruction of airflow; 2) **Vowels** are produced when the flow of air is relatively unobstructed and they form the center (nucleus) of a syllable.

2.2.1 Consonants: Features of Articulation

Every consonant can be described as a combination of the following three features.

- voiced or voiceless (state of the glottis)
- place of articulation
- manner of articulation

The details are in Fig 1. For example, we can describe [b] as the “voiced bilabial stop".

[s ĩ n]	‘sin’	[s ɪ k]	‘sick’
[b ĩ n]	‘bin’	[f ɪ t]	‘fit’
[w ĩ n d o ʊ]	‘window’	[k ɪ d]	‘kid’
[d ĩ m]	‘dim’	[d ɪ g]	‘dig’
[s ĩ ŋ]	‘sing’	[ɪ f]	‘if’

Table 1: Data for English vowel nasalization.

2.2.2 VOWELS: FEATURES OF ARTICULATION

Every vowel can be described as a combination of the following four features.

- tongue advancement (front, central, or back)
- tongue height (high, mid, or low)
- muscle tense or lax
- lips round or not

The details are in Fig 2. For example, we can describe [u] as the “high back rounded (tense) vowel".

3 PHONOLOGY

3.1 PHONOLOGICAL RULES

Phonological rules take the following form:

/A/ becomes [B] when it occurs in environment C.

Or:

/A/ $\rightarrow$ [B] / C _ D (the conditioning environment)

Note that different brackets (/ / and [ ]) represent different meanings. /A/ represents a **phoneme**, which represents a **natural class** of sounds: a group of sounds in a language that share one or more articulatory or auditory property, to the exclusion of all other sounds in that language. [B] refers to a specific **allophone** of the phoneme.

In the language of computer science, phoneme is like a “class", while allophones are instances of the class. For example, [t] and [ʔ] are both allophones of the phoneme /t/ (voiceless alveolar stop).

Empirically, when we want to find the rules from a set of data, we usually start by making a distribution chart showing the environments (surrounding sounds) of different phonological transformations. Then we make generalizations by identifying the natural class existing in the environments of each type of transformation. We illustrate this process with the examples of English vowel nasalization.

Referring to the data in Table 1, the left column lists environments of the /ɪ/ $\rightarrow$ [ĩ] transformation while the right column list environments for /ɪ/ $\rightarrow$ [ɪ]. By comparing the differences between these two sets of environments, we can conclude that vowels (or in this case, just /ɪ/) become nasalized only when occurring before nasal consonants. We can thus format the phonological rule as:

/ɪ/ $\rightarrow$ [ĩ] / _ nasal consonants

/ɪ/ $\rightarrow$ [ɪ] / everywhere else

3.2 TYPES OF DISTRIBUTION

We define the following types of phonological distribution for pairs of allophones:

- Complementary distribution: allophones of the same phoneme appearing in disjoint environments. For example, [ĩ] (occurs before a nasal consonant) and [ɪ] (occurs elsewhere) are in complementary distribution.

- Contrastive distribution: allophones of different phonemes appearing in same environments, with different meanings. For example, [ɹ] (as in [ɹed]) and [l] (as in [led]) have contrastive distribution.
- Minimal pairs: pairs that differ by only one phoneme, and have different meanings. Minimal pairs imply **contrastive distribution**. E.g., [ɹed] ('red') and [led] ('led') have different meanings and differ only by the first phoneme, and so they form a minimal pair and [ɹ] and [l] are in contrastive distribution.
- Free variation: different allophones of the same phoneme, but appearing in the same environments and having the same meanings. E.g., [bʌtən] and [bʌʔən] have the same meaning "button", so [t] and [ʔ] are free variations in this context.

4 PSYCHOLINGUISTICS IN THE CONTEXT OF PHONOLOGY

In this section, we connect several themes in acquisition to our discussion on phonology. Here we use the term 'psycholinguistics' in a loose sense to refer to anything related to the cognitive aspect of linguistics. We will discuss more about these cognitive aspects from other perspectives in later sections.

4.1 MENTAL GRAMMAR

Our Hypothesis:

Phonological rules are part of mental grammar, and the production pipeline is: Lexicon (stored in mind) → Phonological Transformations (based on phonological rules) → Output.

We didn't talk about any direct evidence for supporting this hypothesis, but we can examine some alternatives and see why they are wrong.

Alternative Hypothesis I:

There are no rules, everything is memorized / stored in our lexicon.

Counter Arguments:

In the wug test by Gleason (1958), a child is presented with an imaginary object and is told, 'This is a wug'. Then a second instance is presented, and the child is asked what the two are called. The correct answer is 'wugs', pronounced with a voiced /z/ sound, as in 'dogs', because the plural-forming letter follows a voiced consonant /g/.

This shows that children can follow rules to generate transformations on **novel** lexicon that they have not seen before.

Alternative Hypothesis II:

Phonological processes are due to physical necessity (or ease of pronunciation).

Counter Arguments:

1. Phonological rules are not cross-lingual, other languages have different rules.
2. Sometimes rules apply even when its environment is not physically present.
   For example, 'writer': /ɹɑɪtəɹ/ first goes through centralization and becomes /ɹʌɪtəɹ/, and then goes through flapping and becomes [ɹʌɪɾəɹ]. Note that in this output /ɑɪ/ is pronounced as [ʌɪ], even though the rule for vowel centralization is /ɑɪ/ → [ʌɪ] / _voiceless. The centralization happens even when the next sound [ɾ] is voiced.
3. The example of **illusory vowels** (Dupoux et al., 1999) suggests that phonological rules affect not just production, not also **perception**.
   It's already known before their work that Japanese speakers have vowel epenthesis (insertion) rules when pronouncing loaned words. For example, they would insert [u] into 'ebzo' and make it 'ebuzo'.
   The authors want to show that the rules apply not only during production, but also influence perception.

They perform speeded ABX task, e.g., first introducing ‘ebuzo’ (A) and ‘ebuuzo’ (B), then playing either A or B and let people decide which one it is.

The results are: Japanese speakers are much better than French speakers (as comparison) in differentiating ‘ebuzo’ and ‘ebuuzo’, but much worse in differentiating ‘ebuzo’ and ‘ebzo’.

This shows that Japanese speakers “hear" illusory vowels that are not really there (due to their vowel epenthesis rule). And this suggests that 1) Phonological rules are part of mental grammar rather than just articulatory processes; 2) Mental grammar influences how we perceive speech. This is a great example of **construction of experience**.

4.2 Construction of Experience

Since we mentioned the term ‘construction of experience (CoE)’ in the previous section, I think it might be a good idea to briefly introduce it here, we will mention it in later sections as well.

In simple words, CoE means that our mind can construct things that are not there. It reflects a mismatch between our perception and the physical reality.

CoE is caused by our existing knowledge or nature of our mind (either learned or innate). We experience or perceive things as if they are present out there in the world, but in fact it is our mind that is creating or constructing it. We will see more CoE examples later.

4.3 Acquisition of Phonology

Our Hypothesis:

Children (10 months - 3+ years) make non-adult pronunciations such as [tɪ] = ‘kiss’ and [hæm] = ‘Sam’. In fact, the errors have patterns and have rule-like processes. This is because **they are applying (non-adult) rules**.

Again, instead of directly proving our hypothesis, we refute some alternative hypotheses.

Alternative Hypothesis:

Perception difficulties: children make errors because they don’t perceive sounds accurately.

Counter Arguments:

There exists **comprehension-production asymmetry**. Evidence suggests that children produce [gʌk] (‘duck’) but when you say “Give me the duck." they can still understand.

In fact, by examining data, there are some **universals** in children’s phonological processes. For example, consonant and vowel harmony, CVCV syllable structures and simplification (i.e., reduction in the number of phones used).

We further expand our hypothesis to the following:

(Not Yet Substantiated) Hypotheses:

- Children have mostly adult-like phonemic representations.
- Children’s “errors" are not all due to simple articulatory difficulties (i.e., not just because they cannot perceive or produce those sounds).
- Children’s phonological transformations are systematic, occurring in particular phonological environment.
- Children initially have non-adult-like phonological rules in production, then start to change to match adult rules.
- Their rules are governed by some universal principles.

4.4 Categorical Perception

4.4.1 Definition

Quoting Wikipedia: “Categorical perception is a phenomenon of perception of distinct categories when there is a gradual change in a variable along a continuum."

Categorical perception is an illustration of construction of experience. It is not unique to language, for example, it happens to human perception of colors as well: different colors are in a continuous spectrum but we perceive them by discrete categories.

4.4.2 Speech Perception of Infants

Categorical perception happens to speech sounds as well, where there is a mismatch between the actual speech signal and our perception due to mental representation of phonemic categories.

For example, [tɑ] and [dɑ] can be differentiated by voice onset time (VOT) - the time between the release of a stop and the voicing of a following vowel. Humans perceive these phonemes categorically while the VOT spectrum of [tɑ] and [dɑ] is in fact continuous. This shows that the mind imposes discrete categories where none exists in the physical world.

However, an arguably more interesting fact about categorical perception is that not just adults, but **infants also perceive speech sounds categorically**.

This finding is from Eimas et al. (1971), where they perform the high amplitude sucking test on babies. Specifically, they use sensors in the pacifier to monitor babies' sucking rates under stimulus (the stimulus is basically playing different sounds). Initially the sucking rate increases (due to novelty), then it declines to a set point (habituation criterion), that's when experimenters change the auditory stimulus (playing a sound with slightly different VOT). If the infant's sucking rate increases, then it suggests that the infant has detected the change.

The experiment results suggest that newborns not only have categorical perception, moreover they are "**universal listeners**": newborns are sensitive to many different distinctions, not necessarily the same as their exposure language. However, **adults have difficulty distinguishing such non-native contrasts**. This change of speech perception in infants as they grow up is mainly discovered by Janet Werker.

Werker & Tees (1984) tested different groups of people on differentiating Hindi contrasts.

We already saw that we can use high amplitude sucking and habituation to test 0-5 months infants. The methodology for testing 6-12 months babies that they used is conditioned head turning: infants are trained with 2 clearly different auditory stimuli (bell and whistle) and the toy is activated as the reward only if the sound changes and the baby turns to look at it. For example, the infant hears stimulus 1 (/ba/) repeatedly and then stimulus 2 (/da/) is presented. If the infant detects difference, they should turn to look at the toy when the stimulus changes.

Based on such experiments, they find that Hindi adults and (6-8 months) English babies can differentiate Hindi contrasts, while English adults cannot. They further show that babies' ability to perceive non-native contrasts declines in their 1st year.

Again, there are several hypotheses for explaining such changes:

Hypothesis I:

The role of experience is to maintain perceptual sensitivities and so the lack of exposure leads to loss of perceptual ability (brain cell atrophy).

Counter Arguments:

Following this hypothesis, we would expect that the decline in sensitivity due to lack of exposure should be permanent and absolute.

However, adults can indeed perceive non-native contrasts in non-speech tasks or on speech tasks after training. Also, children older than 12 months can move to a new country and acquire the local native phonology (note: I didn't get time to substantiate this statement with scientific evidence, so take it with a grain of salt). So, there is no absolute hardware change in auditory system.

Hypothesis II:

The preset discrete categories are from our general auditory system, and that is separate from our linguistic system (i.e., mental grammar) developing over time. Both exist, but are not necessarily always in use. This is the hypothesis preferred by Tonia in the lectures. More specifically, the proposed pipeline works as the following:

For linguistic inputs, the raw inputs first go through the general auditory system, and then our mental grammar. Due to the transformations imposed by our mental grammar, we cannot detect the differences between these contrasts.

For non-linguistic inputs: they only go through the general auditory system (without undergoing the transformations in mental grammar), and so we can detect differences.

Other animals have categorical perception as well, e.g., chinchillas (Kuhl & Miller, 1978). Their experiments involve shocking animals so I will not describe in detail.

5 MORPHOLOGY

5.1 DEFINITION

Morpheme refers to the smallest unit that has meaning in a language. A morpheme should have consistent pronunciation and meaning. Morphology basically studies how morphemes form words.

A **bound** morpheme is a morpheme that cannot stand alone as a word and is subject to rules for combination (e.g., prefixes and suffixes). In contrast, a **free** morpheme can stand alone as a word and cannot be broken down further into other morphemes.

There are two types of morphological transformation. Morphological **derivation** means to create or derive a new word (which involves a change in meaning or part-of-speech). For example, 'contain' → 'containable', 'transform' → 'transformation', 'weak' → 'weaken', and 'happy' → 'unhappy'. Morphological **inflection** means to produce a different form of the same word (which does not change the part-of-speech). For example, 'walk' → 'walked', 'cat' → 'cats', and 'tall' → 'taller'. I think another interesting example is that 'friend' → 'friendship' is considered derivation because there is a change in the meaning.

When a transformation involves both derivation and inflection, inflection is applied **after** derivation.

5.2 MORPHOLOGICAL RULES

For example, based on the data: "rewash", "reload", "redo", etc. We can abstract the following morphological rule:

re- + V = V (meaning: to V again)

Similarly, we can derive the rule:

Adj + -ness = N (e.g., happy → happiness)

Note that the same affix can correspond to different morphemes if they have different meanings. For example, consider the 'er' in:

1) V + -er = N (one who Vs); and 2) Adj + -er = Adj (comparative, more Adj)

They are two different morphemes (homonyms).

5.3 ALLOMORPHY

Although in cases like [z] in 'dogs' vs [s] in 'cats', the plural morpheme seems to have different pronunciations, they are considered as different **allomorphs** of the same morpheme. This means that they are different pronunciations of the **same morpheme**, and the difference is due to phonological rules. The process can be summarized as the following:

Lexicon → Morphology → Phonology

The same reasoning would give us the conclusion that 'in-' (as in 'inhumane', 'indecisive', 'inaccurate') and 'im-' (as in 'impractical', 'immortal', 'immature') are the same morpheme. The morphological rule is: /ɪn/ + Adj = Adj (the opposite meaning). The phonological rule applied upon this morphological transformation is: /n/ → [m] / _ bilabial.

On the contrary, 'in-' and 'un-' (e.g., 'undeniable') are not allomorphs of the same morpheme because there are no phonological rules accounting for the difference (they can actually appear in similar environments). The same goes for '-ity' and '-ness', which are considered two separate morphemes despite that they can both attach to adjectives to form nouns.

5.4 Multiple Rule Application

When there are multiple morphological rules applied together, the order is based on the tree structure of the word. For example, consider the formation of 'unkindness'. There are two possible paths:

- 1) 'kind' + '-ness' → 'kindness'; 2) 'un-' + 'kindness' → 'unkindness'. (Wrong)
- 1) 'un-' + 'kind' → 'unkind'; 2) 'unkind' + '-ness' → 'unkindness'. (Correct)

Only the second path is correct, because in the first path, there's no such rule as 'un-' + N = N.

Moreover, the constituent structure of the word reflects its meaning. For example, 'misreapply' means to reapply poorly, while 'remisapply' means to apply poorly again.

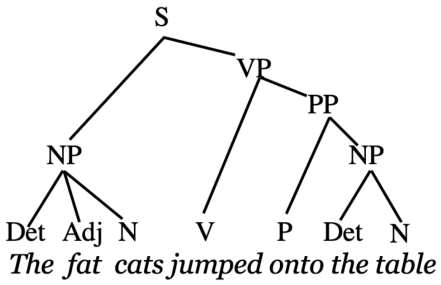

Figure 3: An example of a syntax tree.

6 Syntax

While phonology and morphology focus on the word (or sub-word) level, syntax focuses on rules at the sentence level. In syntax, we are interested in understanding how words compose sentences.

6.1 Hierarchical Structure

It's easy to see that the linear order or the words matters for the sentence. For example, consider the sentence *'The two grey cats chased a mouse.'* Shuffling the word order would most likely results in an ungrammatical sentence. (And we had a paper about using word shuffling to probe language models (Si et al., 2019)!) Switching the order of some words in the sentence can also result in a sentence with different meanings: *'A mouse chased the two grey cats.'*

However, linear order isn't all that matters. In fact, our syntactic rules depend on the **hierarchical structure** of sentences rather than the linear orders. Let's consider the sentence *'Alex poked the monkey with the banana.'*. We see that this sentence has structural ambiguity: the same word order can have two different meanings (Alex used the banana to poke the monkey, or Alex poked the specific monkey that had a banana).

In fact, we can represent the hierarchical structure of a sentence with a syntax (or parse) tree. We show an example of a syntax tree in Fig 3. We can see that each leaf node corresponds to a word, each non-leaf node corresponds to a **constituent**, and the root node corresponds to the entire sentence. Every node is also labeled with its syntactic category. We list the common syntactic categories below in Table 2. Note that here we condense different types of verbs (e.g., transitive and intransitive verb) into the broad V (verb) category. We will talk about the fine-grained differences later. While most of them are rather self-explanatory, I want to highlight that a complementizer is used to introduce a clause (like a sub-sentence) within the main/root sentence. For simplicity we will denote the clause after the complementizer as S'.

Syntactic Category	Example
S (sentence)	Fluffy is cute.
NP (noun phrase)	she, the cute cat
N (noun)	cat
Det (determiner)	the, every, this
Adj (adjective)	cute, flutty
VP (verb phrase)	slept, liked Bob, wrote the letter quickly
V (verb)	liked, gave, said
Adv (adverb)	quickly, tomorrow
P (proposition)	at, for, with
PP (propositional phrase)	at the table, for Sally
Aux (auxiliary verb)	will, can, must
Comp (complementizer)	that, if

Table 2: Major syntactic categories in English.

6.2 CONSTITUENTS

There are several ways to determine whether a phrase is a constituent of the sentence or not. We introduce three of them:

Test 1: Substitution by Pro-forms.

If a group of words can be replaced by a pro-form and the resulting sentence retains the original meaning, then it is a constituent.

Consider the original sentence: *'The fat cats jumped onto the table.'*

We can transform it to:

(Context: The dogs jumped onto the table, and) *the fat cats* ***did so***, too.

This shows that *'jumped onto the table'* is a constituent.

On the other hand, if we do the transformation:

The ***they*** *jumped onto the table.*

We get an ungrammatical sentence. Thus *'fat cats'* fails the pro-form test.

Test 2: Clefting.

If a group of words can move around as a unit, it is a constituent.

For the same original sentence: *'The fat cats jumped onto the table.'*

We can apply clefting and get:

It was ***onto the table*** *that the fat cats jumped.*

The resulted sentence is grammatical and retained the original meaning, and so *'onto the table'* is indeed a constituent.

Test 3: Question Answering.

If a group of words can stand alone as the answer to a question, then it is a constituent.

For the same original sentence: *'The fat cats jumped onto the table.'*

We can construct the following QA pairs:

Q: Who jumped onto the table? A: the fat cats

Q: What did the fat cats do? A: jumped onto the table

*Q: *What did the fat do onto the table? A: *cats jumped*

We see that the first two QA pairs are valid and show that *'the fat cats'* and *'jumped onto the table'* are constituents of the sentence. On the contrary, the last QA pair is ungrammatical and fails the test.

In general, if a group of words passes one of the above tests, then it is considered a constituent. However, failing one test doesn't necessarily mean that it will also fail the other tests. We can only conclude that the phrase is not a constituent if it fails all the tests.

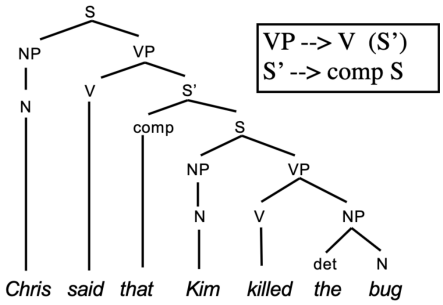

Figure 4: An example of how to use complementizers in the sentence. The corresponding phrase structure rules involving the complementizer are shown in the upper-right box.

6.3 Phrase Structure Rules

There are two types of syntactic rules: rules that build the sentence structure are called **phrase structure rules**; rules that change the sentence structure are called **transformations**.

In this section, we look at phrase structure rules, which represent possible combinations of words and phrases. We can draw syntax trees for sentences and then extract the underlying phrase structure rules. For example, we can extract the following set of phrase structure rules from a set of common sentences:

S $\rightarrow$ NP (Aux) VP

NP $\rightarrow$ (Det) (AdjP+) N (PP+)

VP $\rightarrow$ VP PP

VP $\rightarrow$ V (NP) (PP)

VP $\rightarrow$ V S'

S' $\rightarrow$ Comp S

PP $\rightarrow$ P NP

AdjP $\rightarrow$ (Adv) Adj

Brackets indicate that the constituent is optional, and '+' indicates that there can be multiple such constituents. We presented an example sentence in Fig 4 for the rules involving complementizers.

Interestingly, from the phrase structure rules, we can observe the case of **recursion**. For non-CS people, a rule is recursive if it can apply to its own output. For example, we can have the following recursive cycle:

S $\rightarrow$ NP (Aux) VP $\implies$ VP $\rightarrow$ V S' $\implies$ S' $\rightarrow$ Comp S $\implies$ S $\rightarrow$ NP (Aux) VP $\cdots$

The above cycle can go on and on, which can lead to unboundedly long sentences and infinitely many sentences. For example, using the above recursion you can generate something like 'Sam heard that Chris said that Kim knew that ...'

6.4 VERBS

As promised, we devote this brief section discussing different types of verbs. We mainly discuss three types of verbs:

- Transitive verbs (V_{TR}) need an NP complement to form a VP, for example, *'kill a bug'*.
- Intransitive verbs (V_{IN}) can stand alone as a VP, for example, *'slept'*.
- Ditransitive verbs (V_{DT}) need two NP complements to form a VP, for example, *'give me the money'*. The two NP complements are sometimes called direct and indirect objects. Note that the indirect object can also take the form of PPs, for example, *'put the cake in the fridge'*.

To differentiate these verbs, we can specify their complements like the following:

chase [_ NP] sleep [_] put [_ NP PP]

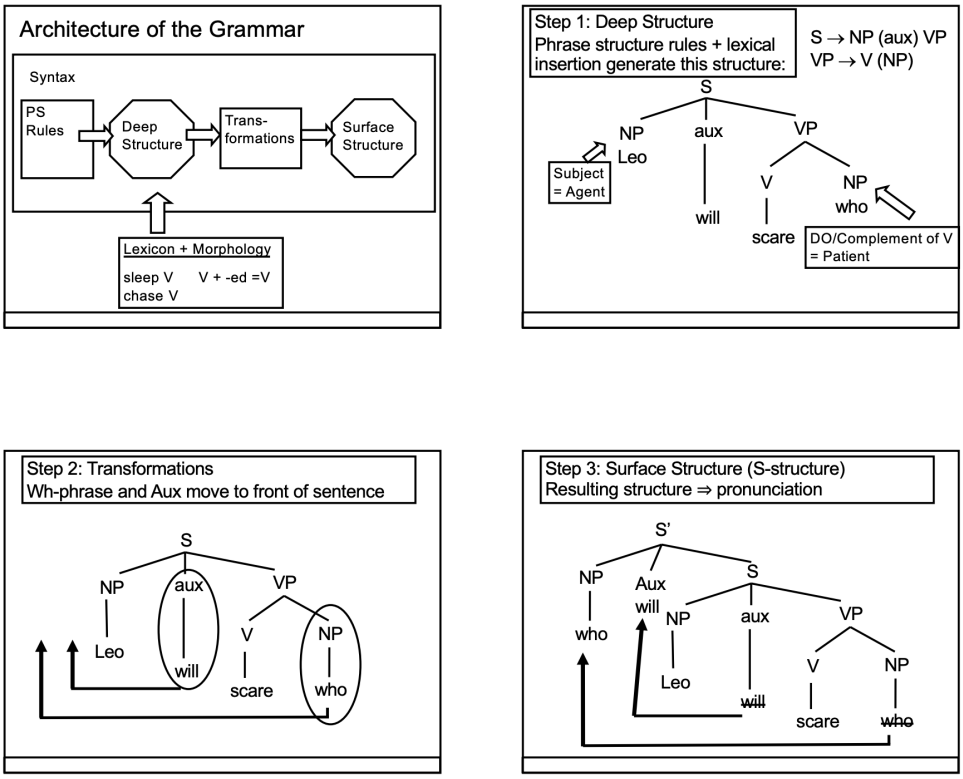

Figure 5: The process of wh- question formation.

6.5 TRANSFORMATIONS

Transformation rules can be applied to sentences in addition to phrase structure rules, and the process works as the following:

PS Rules → Deep Structure of Sentences → Transformations → Surface Structure of Sentences.

We look at question formation as one example of syntactic transformation. Consider the formation of the question: *'Who will Leo scare?'* The deep structure and the transformation process is shown in Fig 5.

Based on the figure, we make some clarification:

- (As mentioned in Step 1 of the figure) Subject/Object is defined in terms of hierarchy in the tree. Subject is the NP child of S (sibling of VP) while the (direct) object is the NP child of VP (sibling of V). In contrast, agent/patient is based on the semantics (i.e., who is imposing the action).
- The transformation rules consist of two steps: 1) Move the wh- phrase (*'who'*) and the Aux *'will'* to the front; 2) Subject-Aux inversion (*'Leo will'* $\rightarrow$ *'will Leo'*). However, note that for yes/no questions, only the second step is needed.

Also, we highlight that transformations are structure dependent: they apply to constituents rather than base on linear orders (more on this later when we discuss poverty of stimulus).

6.6 Islands

Islands refer to certain structures that block movement in the transformation. Consider the following examples:

1) *Sam said that Kim kissed the kid.* $\rightarrow$ *Which kid did Sam say that Kim kissed?*

2) *Sam said [**how** Kim kissed the kid].* $\rightarrow$ **Which kid did Sam say [how Kim kissed]?*

We can see that in the second example, the complementizer *'how'* blocks the movement (wh- island) of the constituent *'the kid'*. In general, you can't move a wh- phrase (*'the kid'*) from within the island to outside the island (the constituent in the square brackets). If you want to ask about which kid, you probably have to settle with something like *'Sam said how Kim kissed which kid?'*

A similar example is: *'John ate [bagels and what] for brunch?'* Here the coordinate structure prevents the fronting of the conjunct (coordinate structure islands).

7 Sign Language

Note that many of the contents of this section are based on the guest lecture of Dr. Deborah Chen Pichler from Gallaudet University.

7.1 Modality Effects

Mary aspects of language are **universal**, applying equally to both spoken and signed languages. Yet modality affects certain aspects of linguistics structure. For example, in terms of phonology, spoken and signed languages have different channels of production (2 hands vs 1 tongue). In terms of lexicon, sign vocabulary is more iconic. Some aspects of sign language grammar are also noticeably iconic.

We describe some modality-specific aspects of signed languages in the following subsections.

7.1.1 Phonology

The sub-lexical units of signs include handshape, location, movement, orientation of hands, facial gestures, etc.

One modality-specific phonological error in the L1 acquisition of sign language is **proximalization**. In this process, infants often sign in bigger movement patterns from the shoulder (the joints most proximal to the torso) and gradually to the wrist and knuckles (the joints most distal to the torso).

Interestingly, sign languages have natural prosodic patterns, and infants are sensitive to these prosodic boundaries even if they have no specific experience with sign languages (Brentari et al., 2011). Six-month-old hearing infants with no sign experience also preferentially attend to sign language stimuli over complex gesture, indicating that they are perceiving sign language as meaningful linguistic input (Krentz & Corina, 2008).

Infants are also sensitive to prosodic and phonological differences between natural sign languages (e.g., BSL vs JSL). In particular, 6-month old hearing, non-signing babies looked longer at the

unfamiliar (new) sign language; while 12-month old babies did not. This early sensitivity to patterns of visual language appears to be innate, since these children had no exposure to any sign language. [2]

7.1.2 LEXICON

Iconic forms look like what they mean. Iconic signs made up 30-34% of the early ASL vocabularies of 13 signing children from Deaf families.

However, for L2 acquisition, Ortega & Morgan (2015) noted reverse correlation between degree of iconicity of BSL signs and phonological accuracy in novice M2L2 (second modality second language) signing. M2L2 signers seem to process iconic signs as gestures (false cognates).

7.1.3 MORPHOLOGY

Most morphology in ASL is simultaneous rather than sequential.

Children also make pronoun reversal errors in ASL. For example, they might say *"You're telling me."* when they meant *"I'm telling you."*

7.2 SINGED LANGUAGES ARE TRUE LANGUAGES

It's important to understand that sign languages are true languages rather than some artificial sign systems. It's true that there is greater iconicity in sign languages. However, it is conventionalized iconicity and not always transparent (it can be hard to infer the meaning from the sign; and also different signed languages are not mutually intelligible - many cross-linguistic differences exist). Overall, there is still a high degree of arbitrariness (relationship between sign and language is arbitrary). Moreover, those apparent iconicty is not used by the signers, as previously mentioned that the iconicty does not aid acquisition. In fact, as sign languages develop over time, the iconicty decreases.

8 LANGUAGE ACQUISITION

We touched a little bit on acquisition when talking about phonology. We will talk about some other aspects of language acquisition in this section. Our discussion is also closely connected to the discussion on universal grammar in the next section.

8.1 WORD LEARNING

There are several guiding principles for learning **nouns**: whole object principle, mutual exclusivity principle, type assumption, and basic level assumption. For example, when you point to a dog and say 'dog', children will pair the word with the dog rather than the fur (or any body part) of the dog, they will pair the word with the species dog rather than that particular dog (say the dog named 'Fibo') or the higher-level 'animal' type, and they will then not use 'dog' to refer to other species.

On the other hand, verb learning is harder than nouns. Despite it being hard, children can use syntactic context to help verb learning, which is known as **syntactic bootstrapping**. For example, if you show children something and say *'This is a zav.'* vs *'This is a zav one.'* 2-3 year-olds can generalize a word's meaning on the basis of 1) color if the word is used in Adj context (*'a zav one'*); 2) shape is the word is used in N context (*'a zav'*).

Another piece of evidence is He & Lidz (2017), where they showed 14-18 month-olds a penguin spinning and say either *'It's a doke.'* or *'It's doking.'*, and the babies can ground the noun to the object while grounding the verb to the action.

This can happen to noun learning as well. For example, when showing *'She's pushing the gop.'* and *'She's pushing with the gop.'* and then ask the children *'Where's the gop'?*, preferential look experiments show that 16-month-olds can choose the appropriate object. This leads to the conclusion that by 16 months, babies can identify the meaning of a novel word based on its position in the sentence

[2] Dr. Deborah cited (Nácar et al., 2017) for this finding but I just couldn't find this particular reference online.

(direct object vs. object of a preposition), despite the fact that they do not produce utterances longer than 1 word long at that time (comprehension precedes production).

8.2 SYNTAX

Seidl et al. (2003) probed the understanding of wh-questions of 15-18 month-olds. The procedure works like the following: they first introduce a set of characters (monkey A, elephant, monkey B). Then they showed that: monkey A washed the elephant, and the elephant washed monkey B. They then ask the children: *'Which monkey washed the elephant?'* and *'Which monkey did the elephant wash?'* Based on preferential looking (which character they looked at for longer), most babies can identify the correct agent for the asked washing action. This leads to the conclusion that by 15-18 months, babies can comprehend questions on the basis of their structure, and distinguish subject and object questions.

Another ongoing work by Mina Hirzel and Jeff Lidz from our linguistics department shows that 3-year-old respect islands. The basic experiment setup is the following: we show that *"She hugged the bear with the blanket."* and ask 1) *"Which blanket was it?"* - This question has two possible interpretations, either asking for the blanket on the bear itself, or the blanket that the experimenter used to hug the bear. 2) We ask *"Which blanket did she hug the bear with?"* - This question only has one interpretation. The experiment results show that when asked the first question, children have a 50-50 chance of choosing either blanket, and when asked the second question, most children identified the correct blanket. This shows how 3-year-olds also follow the island constraints.

Note that we didn't really talk about how children acquire syntax in this class (e.g., semantic bootstrapping), but rather just showed some probing of what children at different ages know about. Hopefully we can get more into this topic in future courses.

9 UNIVERSAL GRAMMAR

9.1 INTRODUCTION

One concept that we've been avoiding in previous sections is the idea of **universal grammar**, which argues that our linguistic system (or mental grammar) is not merely developed from exposure to linguistic inputs, but also has a genetic or innate component known as the universal grammar (UG). We can write it as a succinct formula: **UG + grammar construction based on inputs $\rightarrow$ mental grammar**. This idea is often referred to as **nativism**. In contrast, other people believe that there is no innate component and our mental grammar is purely developed based on experiences. Such thought is referred to as **empiricism**.

Noam Chomsky and other linguists have proposed many arguments and evidence to support nativism, but before we present their arguments, we first make an explicit comparison between nativism and empirism in the following:

Nativism:

- Specialized learning mechanisms for language;
- Nature of linguistic system is determined by innate linguistic principles;
- Children will arrive at the same linguistic system even if in radically different environments;
- Children never make certain kinds of errors (that are against UG), i.e., UG never entertains certain hypotheses;
- Some patterns in inputs are ignored as determined by UG.

Empirism:

- General learning mechanisms - pattern recognition;
- Nature of linguistic system is determined by nature of input;
- Different people should arrive at different kinds of systems if exposed to different inputs;

- Expect children to make a wide range of errors (whatever reasonable extensions of the inputs);
- All patterns in the inputs should receive equal attention.

In the following sections, we present some concrete evidence and arguments for supporting the existence of UG.

9.2 Poverty of the Stimulus

The core idea behind PoS is that our mental grammar can go beyond the experience or inputs that we've been exposed to. We show this via the formation of yes-no questions. As we mentioned the transformation rules section, the formation of yes-no questions involves the subject-aux inversion rule where we move the auxiliary verb to the front. For example, *'Kim **has** been singing.'* → *'**Has** Kim been singing?'*

However, when there is more than one aux in the sentence, we need to decide which aux we should move to the front. For example, consider the example *'Kim **is** saying that Jo **will** leave.'* We know that we should move ***'is'*** to the front. But what's the general rule behind this? There seems to be two possible hypotheses:

Hyp I: Structure-independent Rule.

Move the first (leftmost) auxiliary to the front.

Hyp II: Structure-dependent Rule.

Move the highest auxiliary (in the syntax tree) to the front.

Both hypotheses derive to the correct conclusion that we should move ***'is'*** instead of ***'will'*** in the above example as ***'is'*** is both the first and highest aux.

However, Hyp I doesn't always work. When we have a relative clause after the subject, for example, *'[The child who **is** watching TV] **will** sing.'* Only Hyp II works correctly. In other words, subject-aux inversion rule is stated in terms of structure rather than linear order.

By observing child-directed speech from CHILDES corpus, we observe that the inputs to children are compatible with both hypotheses. However, when tested on inputs requiring the hierarchical rule, children mostly follow the the hierarchical rule (Hyp II) instead of the linear rule (Hyp I).

In fact, McCoy et al. (2018) did the same tests on NLP models and observed some interesting results. You can also find a well-constructed corpus for testing such generalization ability.

From these results, we see that children never entertain certain hypotheses even though they are compatible with the input, which is one evidence for UG.

9.3 Critical Period

Critical period refers to a "window" of opportunity during which the brain is particularly sensitive and primed to learn. We provide some evidence for critical period effects in language acquisition.

We first look at some extreme (and sad) cases where children are not exposed to language during the critical period. Genie was kept by her father in a locked room during her childhood. During that whole time, she didn't have any interaction with others and wasn't exposed to any speech. Genie was discovered at the age of 13, and at that time her cognitive development was roughly equivalent to 15-month-olds. She started to get language exposure and other interactions after being discovered. In 7 months, her cognitive level reached to the level of 4-year-olds.

By examining Genie's language output, people observe that she has acquired: 1) vocabulary (including numbers, colors, question words, etc. but not function words, pronouns or abstract words like 'or'); 2) some word order; 3) negation; 4) some morphology (plurals, possessives, -ing). However, she didn't acquire: 1) inflectional morphology (tense); 2) transformations (e.g., active → passive; wh- questions).

While this is a rare example and there are confounding factors like the abuse by her father in the childhood which caused mental retardation, this still provides some evidence that there is a critical period for acquiring certain linguistic rules like complex syntactic rules relying on hierarchical structures.

Another piece of evidence for critical period comes from Newport (1990). They tested 30 profoundly dead adults aged 35-70 on their acquisition of ASL. The participants include three groups: native learners (exposure from birth), early learners (age of exposure 4-6) and later learners (age of exposure 12+). On basic word order tests, all groups perform pretty well. However, on inflectional morphology tests, native learners are much better than early learners, who are in turn much better than late learners. This shows that 1st language acquisition also has a critical period and some aspects of language may not be learned once past the critical period.

Conceptually, critical period shows a dissociation between language learning and general cognition: after the critical period, language learning becomes much harder, but you can keep getting better at maths by learning and practicing. In fact, subsequent to the critical period (around birth to puberty), primary language by mere exposure is hypothesized to be impossible. Such dissociation suggests that there are specialized learning mechanisms for language, which is separate from other aspects of cognition, as supported by the UG hypothesis.

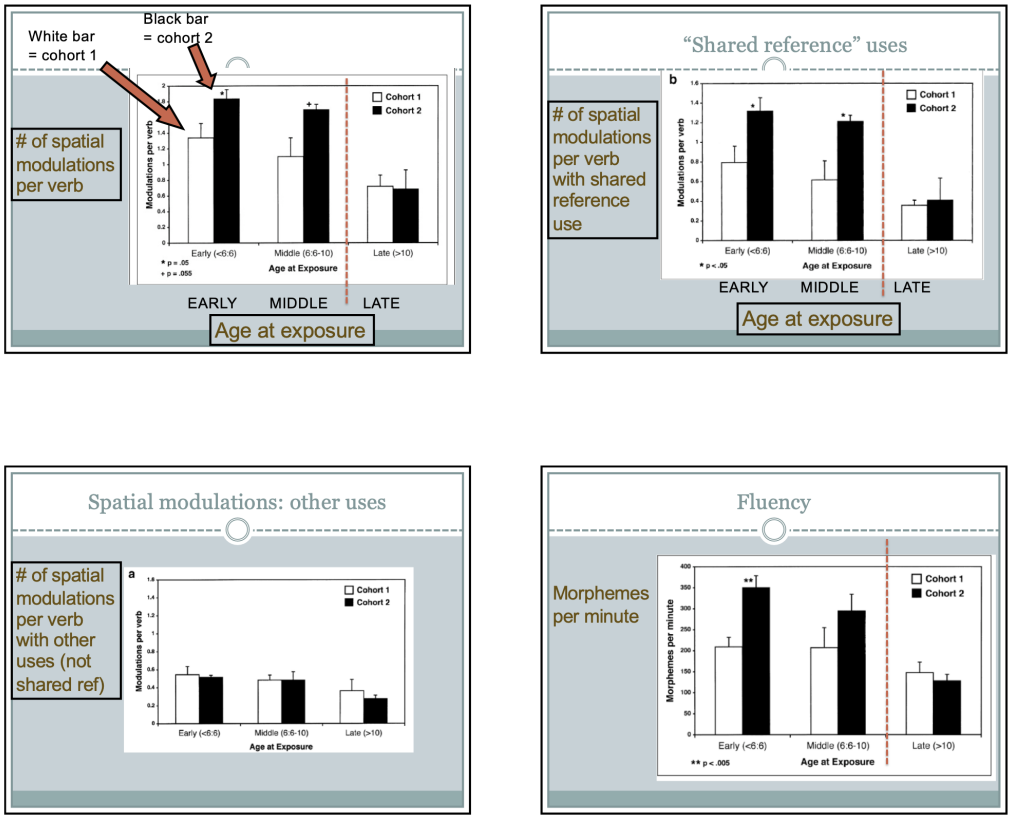

Figure 6: Test results on NSL. The participants are grouped by cohorts and age of exposure.

9.4 The Birth of a New Language

In this section we look at a very interesting case study on Nicaraguan sign language (NSL), which is developed "from scratch" by the dead community at in Nicaragua in the 1980s.

The development of NSL goes through three stages. Firstly, deaf children born to hearing parents who are not exposed to sign language developed an idiosyncratic gestural systems of communication known as ***home sign***. In fact, the development of such home sign is already a case of "going beyond

the input" (PoS) since the children's signs have much consistent patterns (e.g., word order) than their parents. Then, as schools for dead children were opened in Nicaragua, dead children came together and started communicating with each other. During this process, their individual home sign systems emerged into a ***pidgin*** (a grammatically simplified form of a language with limited vocab and variable word order). After that, as generations of children learn pidgin as their native language, they started to create a more complex grammar including innovations not present in the parent languages. This process is known as creolization, during which the pidgin evolved into a ***creole***, which has consistent word order, grammatical constraints and recursive structures (like relative clauses). Apart from these, the function of certain words like indefinite articles also evolved beyond the original pidgin input (again illustrating PoS). You can read Judy Kegl's papers to know more about this whole process.

Senghas & Coppola (2001) did an interesting experiment on these children at Nicaraga. They tested two cohorts: cohort 1 entered school pre-1983 while cohort 2 enter school post-1983. Within each cohort, the children are divided by ago of exposure into three groups: early exposure (before 6.5 yrs), middle expo (6.5-10 yrs), and late expo (after 10 yrs). They tested three aspects: 1) prevalence of spatial modulations; 2) spatial modulation used for grammatical function: indicating "shared reference" (agreement morphology); 3) fluency.

The results are shown in Fig 6. From the first plot, we see that age at exposure has a major impact on the the prevalence of spatial modulation: early and middle groups have much higher prevalence than the late group across both cohorts. At the same time, cohort 2 is much higher than cohort 1. The second and fourth plots show similar trends for the use of spatial modulation for shared reference and the number of morphemes per minute respectively. Taken together, the results can be summarized as: early learners from the 2nd cohort have more spatial modulation in their NSL, with greater use for shared reference and better fluency. This suggests that the 2nd cohort did not just reproduce the input from the previous generations, but rather they changed the language and created rules (PoS). Moreover, children with exposure before 10 also showed more spatial modulation, greater use for shared reference and better fluency compared to other ages of exposure, this supports critical period and indicates that children are responsible for the innovations for the language, not adults :)

9.5 Species Specificity

The last argument for UG that we will discuss is species specificity - only humans, but not other species, can really master human languages. The word 'master' might be a poor choice, but basically what I meant is, learning a few words doesn't count, you need to show understanding of things like syntactic rules.

Terrace et al. (1979) raised a chimp (named Nim Chimpsky) since the age of 2 weeks for 4 years. During that period, Nim has learned 125 signs and mostly produces 2/3/4 word utterances. By analyzing Nim's utterances, they found that: 1) there is lack of evidence for systematic word order; 2) cases of correct word order are often prompted or repetitions of what the teacher had just said; 3) Nim's longer utterances involve many repetitions of same words. The wrong word order and repetition problems are quite obvious is you compare Nim's output with that of a human child. For example, Nim's longest utterance is *"give orange me give eat orange me orange give me eat orange give me you."* Unfortunately, there don't seem to be many experiments on how much (if any) syntax is acquired by Nim - I imagine it would be big news if non-human species can acquire syntax of human language (e.g., compositionality, syntactic categories, hierarchical structure, transformation rules, islands, inflectional morphology, recursion, etc.). But before that, the species specificity does say something about the unique linguistic capabilities of the human species.

9.6 My Conclusion

With all the above being said, I'm not saying (and I hope Tonia would agree with me) that we have proved that nativism is 100% correct and empirism is 100% wrong. We have seen some pretty strong evidence for the existence of certain unique linguistic capabilities of human, but UG is too vague as an explanation for all these observations (as vague as the concept mental grammar). Can you enumerate the rules in UG and prove that they are innate? There seems to be many unresolved questions.

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