Psych215L: Language Acquisition

Lecture 18

Grammar & Complex Systems I

Computational Problem: Figure out the order of words (syntax)

Jareth juggles crystals
Subject Verb Object
Noun Verb Noun
NP NP

Depends on grammatical categories like Nouns and Verbs (and their associated phrases (NP)), but also on more precise distinctions like Subjects and Objects.

Some Noun Phrase distinctions:
Subject = usually the agent/actor of the action, "doer": Jareth
Object = usually the recipient of the action, "done to": crystals

Computational Problem: Figure out the order of words (syntax)

Jareth juggles crystals
Subject Verb Object

Important idea: The observable word order speakers produce (like Subject Object Verb) is the result of a system of word order rules that speakers unconsciously use when they speak. This system of word order rules is called syntax.

Computational Problem: Figure out the order of words (syntax)

Jareth juggles crystals
Subject Verb Object

One way to generate Subject Verb Object order:
The linguistic system specifies that order as the general pattern of the language. An example of this kind of system is English.

English Subject Verb Object

Computational Problem: Figure out the order of words (syntax)

Jareth juggles crystals
Subject Verb Object

Another way to generate Subject Verb Object order:
The linguistic system specifies Subject Object Verb as the general pattern, but the Verb in main clauses moves to the second position and some other phrase (like the Subject) moves to the first position. An example language like this is German.

German Subject Object Verb

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German movement rules
____ Verb Subject Object *Verb*

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German movement rules
Subject Verb *Subject* Object *Verb*

Computational Problem: Figure out the order of words (syntax)

Jareth juggles crystals
Subject Verb Object

A third way to generate Subject Verb Object order:
The linguistic system specifies Subject Object Verb as the general pattern, but the Object moves after the Verb in certain contexts (the Object is unexpected information). Kannada is a language like this.

Kannada Subject Object Verb

Computational Problem: Figure out the order of words (syntax)

Jareth juggles crystals
Subject Verb Object

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movement rule

Kannada Subject *Object* Verb Object

Computational Problem: Figure out the order of words (syntax)

Jareth juggles crystals
Subject Verb Object

English
Subject Verb Object

German
Subject Verb *Subject* Object *Verb*

Kannada
Subject *Object* Verb Object

The learning problem: How do children know which system their language uses?

Computational Problem: Figure out the order of words (syntax)

Jareth juggles crystals
Subject Verb Object

English
Subject Verb Object

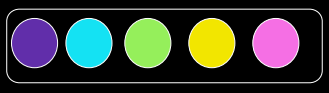
German
Subject Verb *Subject* Object *Verb*

Kannada
Subject *Object* Verb Object

This is a hard question!

Children only see the output of the system (the observable word order of Subject Verb Object).

About Human Knowledge: Language & Variation



Navajo Code Talker Paradox (Baker 2001)

English must be very different from Navajo

Japanese could decode English, but couldn't decode Navajo when they didn't know it was Navajo.

English must be similar to Navajo

English can be translated into Navajo and back with no loss of meaning. (Languages are not just a product of the culture - pastoral Arizona lifestyle couldn't have prepared the code talkers for Pacific Island high tech warfare. Yet, translation was still possible.)

Types of Variation

Vocabulary

English "think" verbs: think, know, wonder, suppose, assume, …

Multiple types of the action verb "think". Each has certain uses that are appropriate.

"I wonder whether the girl saved her little brother from the goblins." [grammatical]

* "I suppose whether the girl saved her little brother from the goblins." [ungrammatical]

Types of Variation

Vocabulary

English "think" verbs: think, know, wonder, suppose, assume, …

Navajo "carry" verbs: depends on object being carried

aah (carry a solid round-ish object)

kaah (carry an open container with contents)

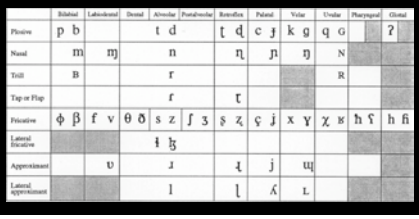
lé (carry a flexible object)

Types of Variation

Sounds: Each language uses a particular subset of the sounds in the International Phonetic Alphabet, which represents all the sounds used in all human languages. There's often overlap (ex: "m", "p" are used in many languages), but languages also may make use of the less common sounds.

less common English sounds: "th" [θ], "th" [ð]

less common Navajo sounds: "whispered l", "nasalized a", …



Types of Variation

Morphology (word forms)
English: invariant word forms
"the girl is crying", "I am crying"

Navajo: no invariant forms (there may be 100-200 prefixes for verb stems)

At'ééd yicha. "Girl crying"

Yishcha. "I am crying"
(yi + sh + cha)

Ninááhwiishdlaad. "I am again plowing"
(ni + náá + ho + hi + sh + l + dlaad)

Types of Variation

Word order (syntax)
English: Subject Verb Object (invariant word order)
"The boy saw the girl"

Navajo: Subject Object Verb, Object Subject Verb
(varying word orders, meaning depends only on verb's form)

Ashkii at'ééd **yiy**iltsá
boy girl saw
"The boy saw the girl"

Ashkii at'ééd **bi**ilstá
boy girl saw
"The girl saw the boy"

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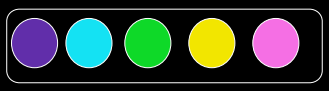
This one prefix changes the entire meaning of the sentence

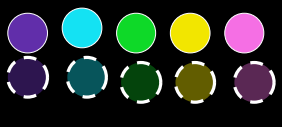
Thinking About Syntactic Variation



Similarities & Differences: Parameters

Chomsky: Different combinations of different basic elements (parameters) would yield the observable languages (similar to the way different combinations of different basic elements in chemistry yield many different-seeming substances).

Big Idea: A relatively small number of syntax parameters yields a large number of different languages' syntactic systems.



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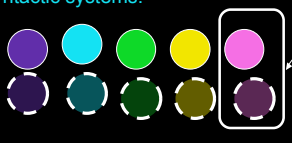

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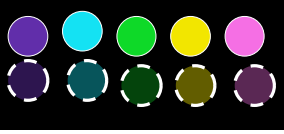

Total languages that can be represented = $2^5 = 32$

Similarities & Differences: Parameters

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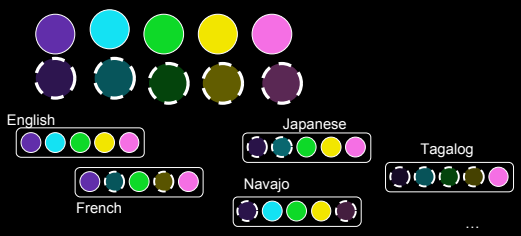
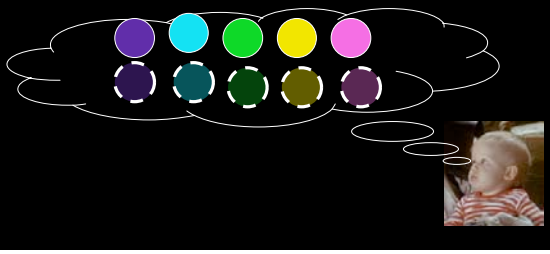


Learning Language Structure

Chomsky: Children are born knowing the parameters of variation. This is part of Universal Grammar. Input from the native linguistic environment determines what values these parameters should have.



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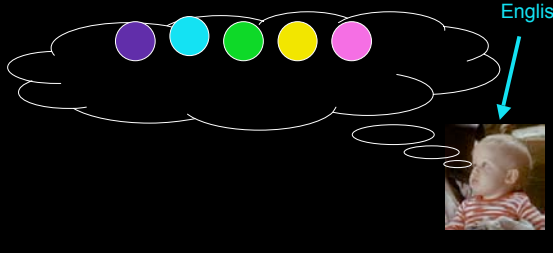

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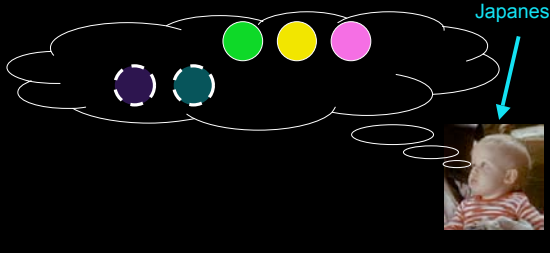
Japanese



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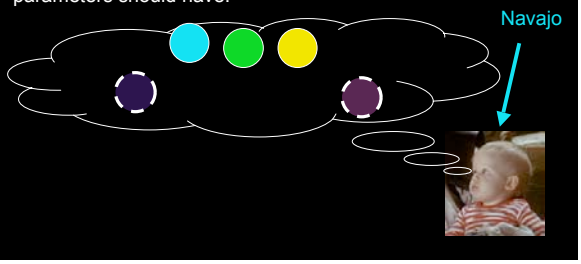


Generalizations About Language Structure

Greenberg's Word Order Generalizations

Navajo

Japanese

Greenberg's Word Order Generalizations

Navajo	Japanese
Basic word order: Subject Object Verb	Basic word order: Subject Object Verb
Ashkii at'ééd yiyiiltsá *boy girl saw*	Jareth-ga Hoggle-o butta *Jareth Hoggle hit*
"The boy saw the girl"	"Jareth hit Hoggle"

Greenberg's Word Order Generalizations

Navajo	Japanese
Postpositions: Noun Phrase Postposition	Postpositions: Noun Phrase Postposition
'éé' biih náásdzá *clothing into I-got-back* "I got back into (my) clothes."	Jareth-ga Sarah to kuruma da *Jareth Sarah with car by* London ni itta *London to went* "Jareth went to London with Sarah by car."

Greenberg's Word Order Generalizations

Navajo	Japanese
Possessor before Possessed	Possessor before Possessed
Possessor Possession	Possessor Possession
Chidí bi-jáád *Car its-leg*	Toby-no imooto-ga *Toby's sister*
"the car's wheel"	"Toby's sister"

Greenberg's Word Order Generalizations

Navajo	Japanese
Basic word order: Subject Object Verb	Basic word order: Subject Object Verb
Postpositions: Noun Phrase Postposition	Postpositions: Noun Phrase Postposition
Possessor before Possessed Possessor Possession	Possessor before Possessed Possessor Possession

Despite the differences in the languages (and their cultural histories), both Japanese and Navajo are very similar when viewed through these three structural descriptions.

Greenberg's Word Order Generalizations

English	Edo (Nigeria)

Greenberg's Word Order Generalizations

English	Edo (Nigeria)
Basic word order: Subject Verb Object	Basic word order: Subject Verb Object
Sarah found Toby	Òzó mién Adésuwá *Ozo found Adesuwa*

Greenberg's Word Order Generalizations

English	Edo (Nigeria)
Prepositions: Preposition Noun Phrase	Prepositions: Preposition Noun Phrase
Jareth gave the crystal to Sarah	Òzó rhié néné ebé né Adésuwá *Ozo gave the book to Adesuwa*

Greenberg's Word Order Generalizations

English	Edo (Nigeria)
Possessed before Possessor	Possessed before Possessor
Possession Possessor	Possession Possessor
quest of Sarah	Omo Ozó child Ozo
(alternative: Sarah's quest)	"child of Ozo"

Greenberg's Word Order Generalizations

English	Edo (Nigeria)
Basic word order: Subject Verb Object	Basic word order: Subject Verb Object
Prepositions: Preposition Noun Phrase	Prepositions: Preposition Noun Phrase
Possessed before Possessor Possession Possessor	Possessed before Possessor Possession Possessor

Again, despite the differences in the languages (and their cultural histories), both English and Edo are very similar when viewed through these three structural descriptions.

Greenberg's Word Order Generalizations

Greenberg found forty-five "universals" of languages - patterns overwhelmingly followed by languages with unshared history (Navajo & Japanese, English & Edo)

Not all combinations are possible - some patterns rarely appear
Ex: Subject Verb Object language (English/Edo-like) + postpositions (Navajo/Japanese-like)

Moral: Languages may be more similar than they first appear "on the surface", especially if we consider their structural properties.

More Language Comparisons

French	Italian
Subject Verb	Subject Verb
Jareth arrivera	Jareth verrá
Jareth will-come	*Jareth will-come*
"Jareth will come."	"Jareth will come."
grammatical	grammatical

More Language Comparisons

French	Italian
*Verb Subject	Verb Subject
*Arrivera Jareth	Verrá Jareth
**Will-arrive Jareth*	*Will-arrive Jareth*
"Jareth will arrive"	"Jareth will arrive"
ungrammatical	grammatical

More Language Comparisons

French	Italian
*Verb	Verb
*Arrivera	Verrá
He-will-come	*He-will-come*
"He will come"	"He will come"
ungrammatical	grammatical

More Language Comparisons

French	Italian
Subject Verb	Subject Verb
*Verb Subject	Verb Subject
*Verb	Verb

These word order patterns might be fairly easy to notice. They involve the combinations of Subject and Verb that are grammatical in the language. A child might be able to notice the prevalence of some patterns and the absence of others.

More Language Comparisons

Expletive subjects: words without content (may be more difficult to notice)

French	Italian
*Pleut It-rains. "It's raining"	Piove. It-rains. "It's raining."
Il pleut. It rains. "It's raining."	
Not okay to leave out expletive subject "it".	Okay to leave out expletive subject "it".

More Language Comparisons

Embedded Subject-Question Formation (easy to miss)

French	Italian
Tu veux que Marie épouse Jay. *You want that Marie marries Jay.* "You want Marie to marry Jay."	
*Qui veux-tu que ___ épouse Jay? Que veux-tu qui ___ épouse Jay? *Who want-you that marries Jay?* "Who do you want to marry Jay?"	
Requires a special "that" form: qui.	

More Language Comparisons

Embedded Subject-Question Formation (easy to miss)

French	Italian
	Credi che Jareth verrá. *You think that Jareth will-come.* "You think that Jareth will come."
	Che credi che __ verrá? *Who think-you that will-come?* "Who do you think will come?"
	Does not require a special "that" form: use the same one as normally is used - *che*.

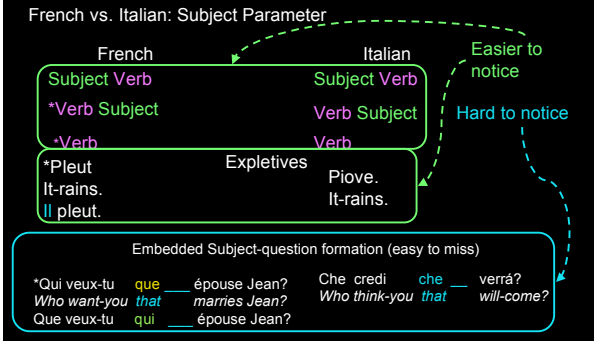
More Language Comparisons

French	Italian
Subject Verb	Subject Verb
*Verb Subject	Verb Subject
*Verb	Verb
Not okay to leave out expletive subject "it".	Okay to leave out expletive subject "it".
Requires special action for embedded subject questions.	Does not require special action for embedded subject questions.

All these involve the subject in some way - coincidence?
Idea: No! There's a language parameter involving the subject.

The Value of Parameters: Learning the Hard Stuff by Noticing the Easy Patterns

French vs. Italian: Subject Parameter



The Value of Parameters: Learning the Hard Stuff by Noticing the Easy Patterns

French vs. Italian: Subject Parameter

Big idea: If all these structural patterns are generated from the same linguistic parameter (e.g. a "subject" parameter), then children can learn the hard-to-notice patterns (like the patterns of embedded subject questions) by being exposed to the easy-to-notice patterns (like the optional use of subjects with verbs). The hard-to-notice patterns are generated by one setting of the parameter, which children can learn from the easy-to-notice patterns.

Children's knowledge of language structure variation is believed by nativists to be part of Universal Grammar, which children are born with.

Universal Grammar: Principles & Parameters

Principles: Apply to all human languages.
Ex: Language has hierarchical structure.
Smaller units are chunked into larger units.

sounds	g a b l ɪ n
syllables	g a b l ɪ n
words	goblin
phrases	Noun Phrase (NP): The sneaky goblin; Verb Phrase (VP): stole the baby
sentences	S → NP (The sneaky goblin) VP (stole the baby)

Universal Grammar: Principles & Parameters

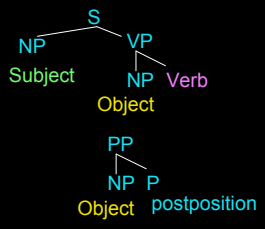
Parameters: Constrained variation across languages. Children must learn which option their native language uses.

Japanese/Navajo

Basic word order:
Subject Object Verb

Postpositions:
Noun Phrase Postposition

Possessor before Possessed
Possessor Possession



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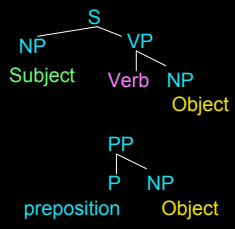
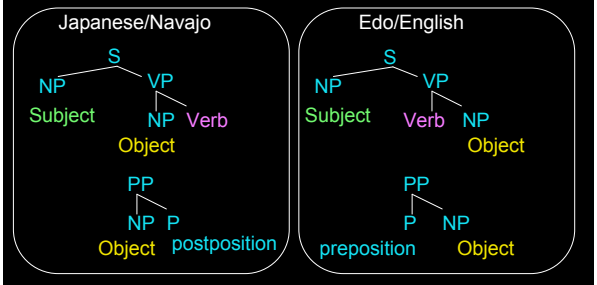


Universal Grammar: Principles & Parameters

At this level of structural analysis (parameters), languages differ vary minimally from each other. This makes language structure much easier for children to learn. All they need to do is set the right parameters for their language, based on the data that are easy to observe.



Language Variation: Summary

While languages may differ on many levels, they have many similarities at the level of language structure (syntax). Even languages with no shared history seem to share similar structural patterns.

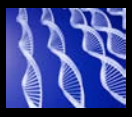
One way for children to learn the complex structures of their language is to have them already be aware of the ways in which human languages can vary. Nativists believe this is knowledge contained in Universal Grammar. Then, children listen to their native language data to decide which patterns their native language follows.

Languages can be thought to vary structurally on a number of linguistic parameters. One purpose of parameters is to explain how children learn some hard-to-notice structural properties.

Yang (2004): Learning Complex Systems Like Language

Only humans seem able to learn human languages

Something in our biology must allow us to do this.



This is what Universal Grammar is: innate biases for learning language that are available to humans because of our biological makeup (specifically, the biology of our brains).

Chomsky

Yang (2004): Learning Complex Systems Like Language

But obviously language is *learned*, so children can't know everything beforehand. How does this fit with the idea of innate biases/knowledge?

Observation: we see constrained variation across languages in their sounds, words, and structure. The knowledge of the ways in which languages vary is children's innate knowledge.

English

Navajo

Children know parameters of language variation…which they use to learn their native language

Yang (2004): Learning Complex Systems Like Language

The big point: even if children have innate knowledge of language structure, we still need to understand how they learn what the correct structural properties are for their particular language. One idea is to remember that children are good at tracking statistical information (like transitional probabilities) in the language data they hear.

English

Navajo

Children know parameters of language variation…which they use to learn their native language

Yang (2004): Learning Complex Systems

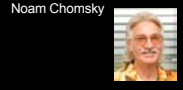
The linguist-psychologist breakdown

Linguists

Characterize "scope and limits of innate principles of Universal Grammar that govern the world's languages".

Noam Chomsky

David Lightfoot



Stephen Crain

Psychologists

Emphasize the "role of experience and the child's domain-general learning ability".

Michael Tomasello

Elizabeth Bates

Brian MacWhinney

Yang (2004): Learning Complex Systems

Statistics for word segmentation (remember Gambell & Yang (2006))

"Modeling shows that the statistical learning (Saffran et al. 1996) does not reliably segment words such as those in child-directed English. Specifically, precision is 41.6%, recall is 23.3%. In other words, about 60% of words postulated by the statistical learner are not English words, and almost 80% of actual English words are not extracted. This is so even under favorable learning conditions".

Unconstrained (simple) statistics: not so good.

If statistical measure is constrained by language-specific knowledge (words have only one main stress), performance increases dramatically: 73.5% precision, 71.2% recall.

Constrained statistics - much better!

Yang (2004): Learning Complex Systems

Combining statistics with Universal Grammar

A big deal:
"Although infants seem to keep track of statistical information, any conclusion drawn from such findings must presuppose that children know *what kind* of statistical information to keep track of."

Ex: Transitional Probability

…of rhyming syllables?
…of syllables with nasal consonants?
…of syllables of the form CV (ba, ti)?

Yang (2004): Learning Complex Systems

Universal Grammar: Principles & Parameters

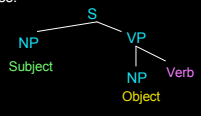
Parameters: Constrained variation across languages. Child must learn which option native language uses.

Japanese/Navajo

Basic word order:
Subject Object Verb

Postpositions:
Noun Phrase Postposition

Possessor before Possessed
Possessor Possession

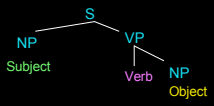


Edo/English

Basic word order:
Subject Verb Object

Prepositions:
Preposition Noun Phrase

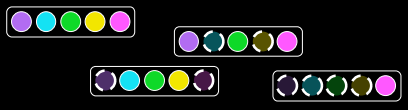
Possessed before Possessor
Possession Possessor



Linguistic Knowledge for Learning Structure

Parameters = constraints on language variation. Only certain rules/patterns are possible. This is linguistic knowledge.

A language's grammar
= combination of language rules
= combination of parameter values



Idea: use statistical learning to learn which value (for each parameter) that the native language uses for its grammar. This is a combination of using linguistic knowledge & statistical learning.

Yang (2004): Variational Learning

Idea taken from evolutionary biology:
In a population, individuals compete against each other. The fittest individuals survive while the others die out.

How do we translate this to learning language structure?

Yang (2004): Variational Learning

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In a population, individuals compete against each other. The fittest individuals survive while the others die out.

How do we translate this to learning language structure?

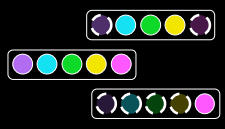
Individual = grammar (combination of parameter values that represents the structural properties of a language)

Fitness = how well a grammar can analyze the data the child encounters

Yang (2004): Variational Learning

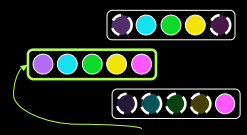
Idea taken from evolutionary biology:
A child's mind consists of a population of grammars that are competing to analyze the data in the child's native language.

Population of Grammars



Yang (2004): Variational Learning

Intuition: The most successful (fittest) grammar will be the native language grammar because it can analyze all the data the child encounters. This grammar will "win", once the child encounters enough native language data because none of the other competing grammars can analyze all the data.



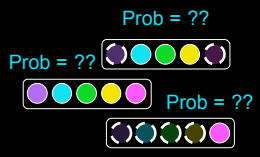
Native language data point

"It's raining."

This grammar can analyze the data point while the other two can't.

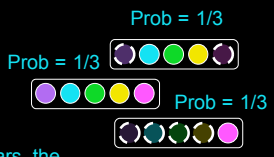
Variational Learning Details

At any point in time, a grammar in the population will have a probability associated with it. This represents the child's belief that this grammar is the correct grammar for the native language.



Variational Learning Details

Before the child has encountered any native language data, all grammars are equally likely. So, initially all grammars have the same probability, which is 1 divided the number of grammars available.



If there are 3 grammars, the initial probability for any given grammar = 1/3

Variational Learning Details

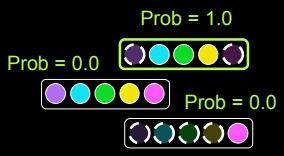
As the child encounters data from the native language, some of the grammars will be more fit because they are better able to account for the structural properties in the data.

Other grammars will be less fit because they cannot account for some of the data encountered.

Grammars that are more compatible with the native language data will have their probabilities increased while grammars that are less compatible will have their probabilities decreased over time.

Variational Learning Details

After the child has encountered enough data from the native language, the native language grammar should have a probability near 1.0 while the other grammars have a probability near 0.0.



Variational Learning Details

How do we know if a grammar can successfully analyze a data point or not?

Example: Suppose  is the subject-drop parameter.

 is +subject-drop, which means the language may optionally choose to leave out the subject of the sentence, like in Spanish.

 is -subject-drop, which means the language must always have a subject in a sentence, like English.

Here, one grammar is +subject-drop while two grammars are -subject-drop.

Variational Learning Details

How do we know if a grammar can successfully analyze a data point or not?

Example data: Vamos = *coming-1st-pl* = "We're coming"

 The +subject-drop grammar is able to analyze this data point as the speaker optionally dropping the subject.

 The -subject-drop grammars cannot analyze this data point since they require sentences to have a subject.

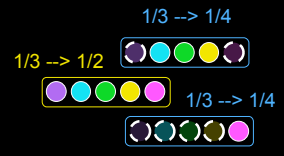
Variational Learning Details

How do we know if a grammar can successfully analyze a data point or not?

Example data: Vamos = *coming-1st-pl* = "We're coming"

 The +subject-drop grammar would have its probability increased if it tried to analyze the data point.

 The -subject-drop grammars would have their probabilities decreased if either of them tried to analyze the data point.

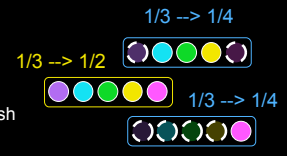


Variational Learning Details

Important idea: From the perspective of the subject-drop parameter, certain data will only be compatible with +subject-drop grammars. These data will always reward grammars with +subject-drop and always punish grammars with -subject-drop.

 Certain data always reward +subject-drop grammar(s).

 Certain data always punish -subject-drop grammar(s).



These are called unambiguous data for the +subject-drop parameter value because they unambiguously indicate which parameter value is correct (here: +subject-drop) for the native language.

The Power of Unambiguous Data

Unambiguous data from the native language can only be analyzed by grammars that use the native language's parameter value.

This makes unambiguous data very influential data for the child to encounter, since it is incompatible with the parameter value that is incorrect for the native language.

Ex: the -subject-drop parameter value is not compatible with sentences that drop the subject. So, these sentences are unambiguous data for the +subject-drop parameter value.

Important to remember: To use the information in these data, the child must know the subject-drop parameter exists.

Yang (2004): Learning Complex Systems

Learning Parametric Systems: Variational Learning

Grammars compete against each other to see which can best analyze the available data.

Added perk: Learning is then gradual (probabilistic).

Problem: Does unambiguous data exist for entire grammars?
This requires data that is incompatible with every other possible parameter of every other possible grammar….

Yang (2004): Learning Complex Systems

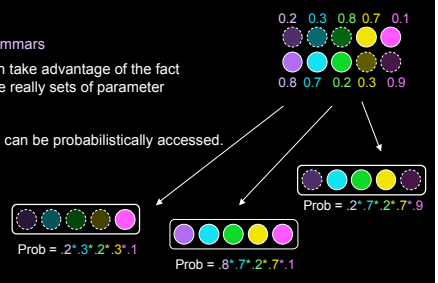
Learning Parametric Systems: Variational Learning

Grammars compete against each other to see which can best analyze the available data.

Parameterized Grammars

This algorithm can take advantage of the fact that grammars are really sets of parameter values.

Parameter values can be probabilistically accessed.



Yang (2004): Learning Complex Systems

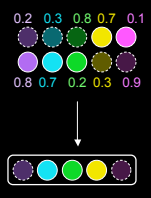
Learning Parametric Systems: Variational Learning

Grammars compete against each other to see which can best analyze the available data.

The Learning Algorithm

For each data point *d* encountered in the input

Choose a grammar probabilistically from available grammars by probabilistically accessing the parameter values.



Yang (2004): Learning Complex Systems

Learning Parametric Systems: Variational Learning

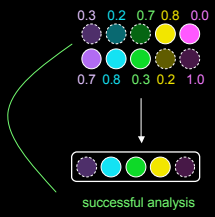
Grammars compete against each other to see which can best analyze the available data.

The Learning Algorithm

For each data point *d* encountered in the input

Choose a grammar probabilistically from available grammars by probabilistically accessing the parameter values.

If this grammar can analyze the data point, increase the probability of all participating parameters values slightly (reward)



Yang (2004): Learning Complex Systems

Learning Parametric Systems: Variational Learning

Grammars compete against each other to see which can best analyze the available data.

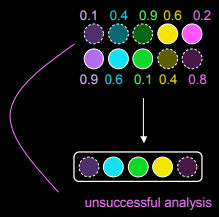
The Learning Algorithm

For each data point *d* encountered in the input

Choose a grammar probabilistically from available grammars by probabilistically accessing the parameter values.

If this grammar can analyze the data point, increase the probability of all participating parameters values slightly (reward)

Else
decrease the probability of all participating parameters values slightly (punish)



Yang (2004): Learning Complex Systems

Learning Parametric Systems: Variational Learning

Grammars compete against each other to see which can best analyze the available data.

Problem ameliorated: unambiguous data much more likely to exist for individual parameter values instead of entire grammars.

Yang (2004): Learning Complex Systems

Variational Learning: Sample Case

Null subjects:

Parameter 1: Pro-drop, rely on unambiguous subject-verb agreement

Ex: Spanish, Italian (+pro-drop)

√ Yo puedo cantar.
I can-1st-sg sing-inf
'I can sing'

√ Puedo cantar.
can-1st-sg sing-inf
'I can sing'

√ Hay lluvia.
Is-3rd-sg rain
"There is rain"

Ex: English (-pro-drop)

√ I can sing

x * Can sing

x * Is rain

√ There is rain.

Yang (2004): Learning Complex Systems

Variational Learning: Sample Case

Null subjects:

Parameter 1: Topic-drop, drop subject/object if discourse topic

Ex: Chinese (+topic-drop) Ex: English (-topic-drop)

(Topic = Jareth)

√ Mingtian guiji hui xiayu.
Tomorrow estimate will rain
'It is tomorrow that *Jareth* believes it will rain'

x *It is tomorrow that believes will rain.

Yang (2004): Learning Complex Systems

Variational Learning: Sample Case

Null subjects: 2 binary parameters, 4 grammars

+pro-drop, +topic-drop
Warlpiri, American Sign Language

+pro-drop, -topic-drop
Italian, Spanish

-pro-drop, +topic-drop
Chinese

-pro-drop, -topic-drop
English

What happens for an English-learning child?

Yang (2004): Learning Complex Systems

Variational Learning: Sample Case

Null subjects: 2 binary parameters, 4 grammars

+pro-drop, +topic-drop
Warlpiri, American Sign Language

+pro-drop, -topic-drop
Italian, Spanish

-pro-drop, +topic-drop
Chinese

-pro-drop, -topic-drop
English

What happens for an English-learning child?

Pro-drop languages depend on rich subject-verb agreement morphology. English doesn't have that, which is something a child will easily notice. Knock out +pro-drop grammars.

Yang (2004): Learning Complex Systems

Variational Learning: Sample Case

Null subjects: 2 binary parameters, 4 grammars

+pro-drop, +topic-drop
Warlpiri, American Sign Language

+pro-drop, -topic-drop
Italian, Spanish

-pro-drop, +topic-drop
Chinese

-pro-drop, -topic-drop
English

What happens for an English-learning child?

But this still leaves the +topic-drop option. What data will rule that out?

Answer: Expletive subjects. (Can't topic-drop them.)
"There's a goblin in the castle."
"It's raining outside."

But this only occurs in 1.2% of the data. (fairly rare)

Yang (2004): Learning Complex Systems

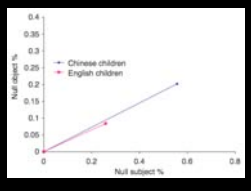
Variational Learning: Sample Case

Null subjects: Prediction if kids take awhile to notice English is -topic-drop

English kids use +topic-drop (Chinese-style) grammar until they encounter enough expletives to notice that English does not optionally drop topics.

Property of Chinese-style grammar: Can drop both subjects and objects

Prediction: When English children use +topic-drop grammar, they will drop subjects and objects at the same relative rate that +topic-drop (Chinese) children do



Same rate:
English children using Chinese grammar

Yang (2004): Learning Complex Systems

Variational Learning: General Predictions

The time course of when a parameter is set depends on how frequent the necessary evidence is in child-directed speech.

Parameters set early: more unambiguous data
Parameters set late: less unambiguous data
Parameters set at the same time: equal quantity of unambiguous data

Parameter	Target language	Requisite evidence	Input (%)	Time of acquisition
Wh fronting[a]	English	*Wh*-questions	25	very early [53]
verb raising[b]	French	verb adverb	7	1;8 [54]
obligatory subject	English	expletive subjects	1.2	3;0 [40,41]
verb second[c]	German/Dutch	OVS sentences [7,35]	1.2	3;0–3;2 [55]
scope marking[d]	English	long-distance *wh*-questions	0.2	4;0+ [56]

[a]English moves *Wh*-words in questions; in languages like Chinese, *Wh*-words stay put.
[b]In language like French, the finite verb moves past negation and adverbs ('Jean voit souvent/pas Marie', 'Jean sees often/not Marie'), in contrast to English.
[c]In most Germanic languages, the finite verb takes the second position in the matrix clause, following one and exactly one phrase (of any type).
[d]In German, Hindi and other languages, long-distance *Wh*-questions leave intermediate copies of *Wh*-markers: "*Wer glaubst du wer Recht hat*?"; 'Who think you who right has?' (Who do you think has right?). For children to know that English doesn't use this the option, long-distance *Wh*-questions must be heard in the input. For many children, the German-option persists for quite some time, producing sentences like "*Who do you think who is the boss*?" [56].