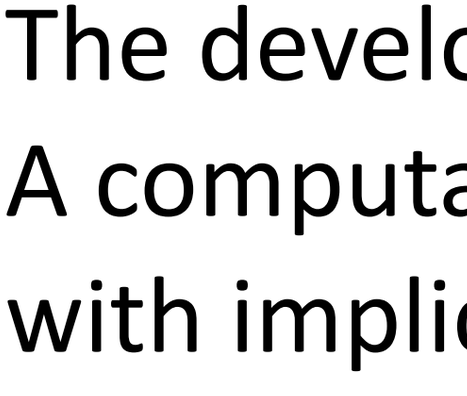
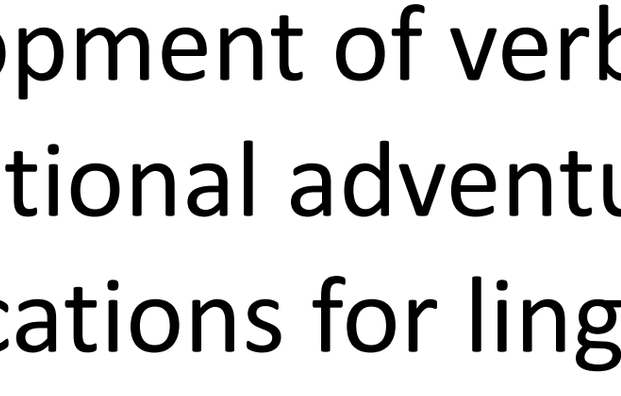
The development of verb classes: A computational adventure with implications for linguistic theory

Lisa Pearl

University of California, Irvine



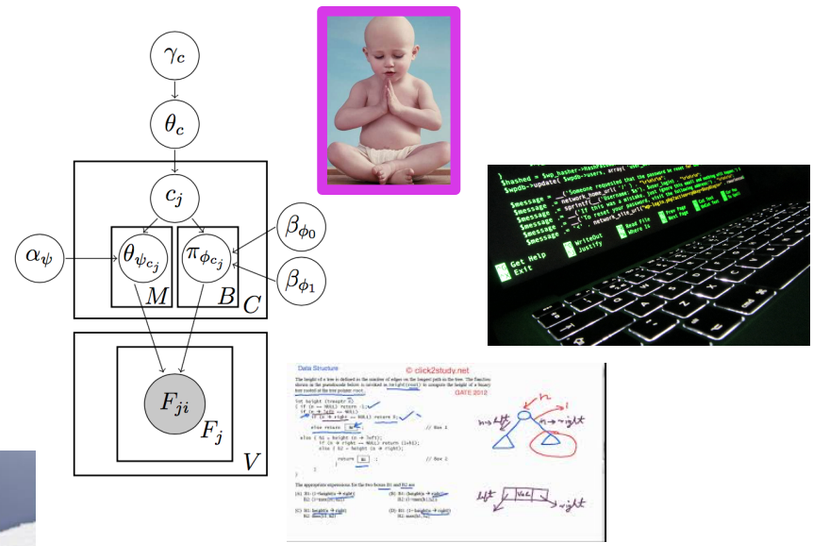


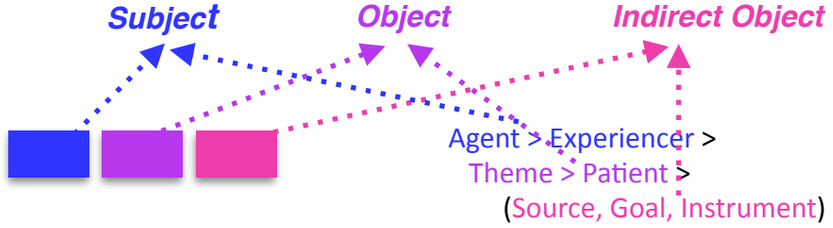
done-to

The ice melted.

The penguin climbed.

doer





June 5, 2017: Language Science Colloquium

University of California, Irvine

Today's plan

Verb classes

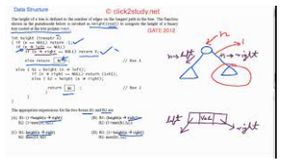
done-to

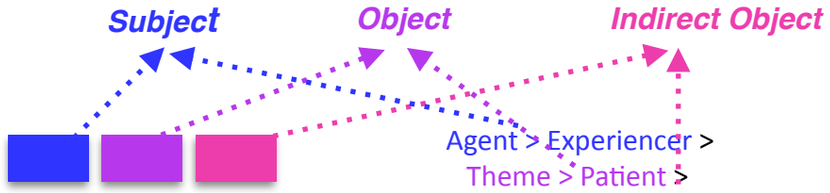
The ice melted.

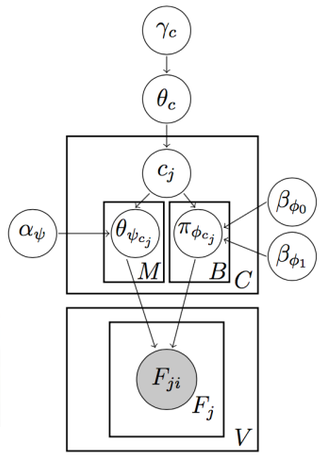
The penguin climbed.

doer

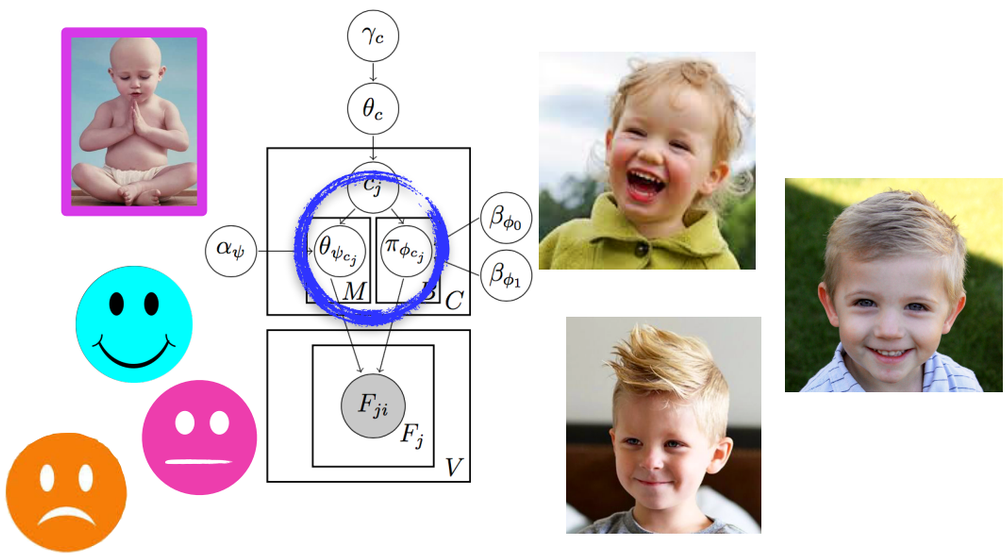
Computational modeling







Results & implications



Today's plan

Verb classes

done-to

The ice melted.

The penguin climbed.

doer

Verb classes

Verbs allow a variety of options for where their arguments appear …

try

She tried to melt the ice.

**It tried that she melted the ice.*

seem

The penguin seemed to climb the hill.

It seemed that the penguin climbed the hill.

Verb classes

Verbs allow a variety of options for where their arguments appear and how they're interpreted.

try

$doer_{melt}$ $doer_{tried}$ $done\text{-}to_{melt}$

She tried to melt the ice.

$doer_{melted}$ $done\text{-}to_{melt}$

**It tried that she melted the ice.*

seem

$doer_{climb}$ $done\text{-}to_{climb}$

The penguin seemed to climb the hill.

$doer_{climb}$ $done\text{-}to_{climb}$

It seemed that the penguin climbed the hill.

Verb classes

Verbs allow a variety of options for where their arguments appear and how they're interpreted.

try

doer$_{melt}$
doer$_{tried}$
She tried to melt the ice.

*****It *tried* that she *melted* the ice.*

melt

doer$_{melted}$ *done-to*$_{melted}$
She melted the ice.

done-to$_{melted}$
The ice was melted.

***done-to*$_{melted}$**
The ice melted.

seem

doer$_{climb}$
The penguin seemed to climb the hill.

It seemed that the penguin climbed the hill.

climb

doer$_{climbed}$ *done-to*$_{climbed}$
The penguin climbed the hill.

done-to$_{climbed}$
The hill was climbed.

***doer*$_{climbed}$**
The penguin climbed.

Verb classes

Each verb has **certain linguistic patterns of behavior**, which are shared with other verbs in the same verb class.

want need

subject-control

try

doer$_{melt}$

doer$_{tried}$

She tried to melt the ice.

**It tried that she melted the ice.*

done-to$_{melted}$

The ice melted.

melt

unaccusative

break fall

appear

subject-raising

seem

doer$_{climb}$

The penguin seemed to climb the hill.

It seemed that the penguin climbed the hill.

doer$_{climbed}$

The penguin climbed.

climb

unergative

laugh dance

Verb classes

How do we tell how a new verb will behave?

The water daxed to blick.

want need

subject-control

try

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doer$_{tried}$

She tried to melt the ice.

**It tried that she melted the ice.*

done-to$_{melted}$

The ice melted.

melt

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doer$_{climb}$

The penguin seemed to climb the hill.

It seemed that the penguin climbed the hill.

doer$_{climbed}$

The penguin climbed.

climb

unergative

laugh dance

Verb classes

We can recognize that it belongs to a specific verb class,
and use that knowledge to predict its behavior.

want need

subject-control

try

doer$_{melt}$

doer$_{tried}$

She tried to melt the ice.

**It tried that she melted the ice.*

It daxed that the water blicked.

appear **dax**

subject-raising

seem

doer$_{climb}$

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done-to$_{melted}$

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blick melt

unaccusative

break fall

doer$_{climbed}$

The penguin climbed.

climb

unergative

laugh dance

done-to$_{blicked}$

The water blicked.

Verb classes

This is what we think kids are doing, too.

want need

subject-control

try

It daxed that the water blicked.

appear **dax**

subject-raising

seem

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blick melt

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climb

unergative

laugh dance

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The water blicked.

Verb classes

Important developmental step:

Grouping verbs into useful **classes**.

melt

unaccusative

break fall

want need

subject-control

try

appear

subject-raising

seem

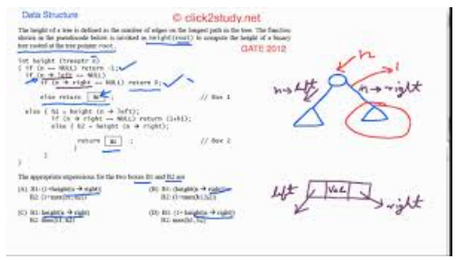
climb

unergative

laugh dance

So how might children do this?

And how can we test different proposals about how they might do this?



Today's plan

Verb classes

done-to

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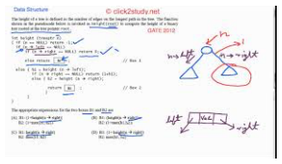
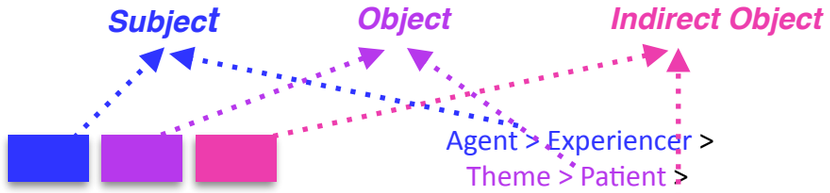
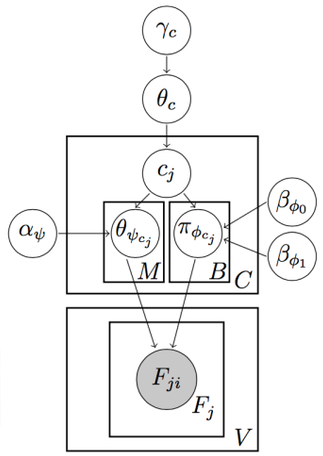
Computational modeling







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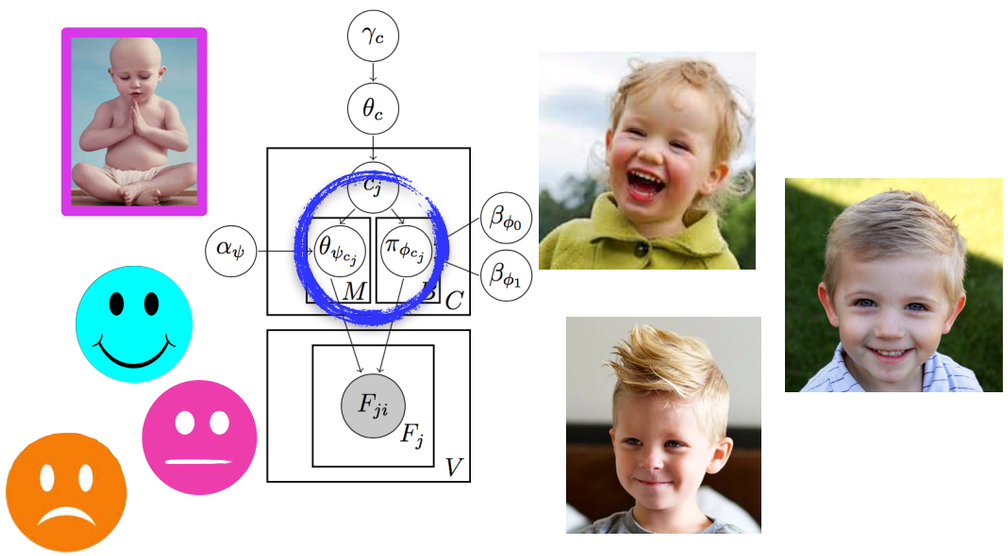
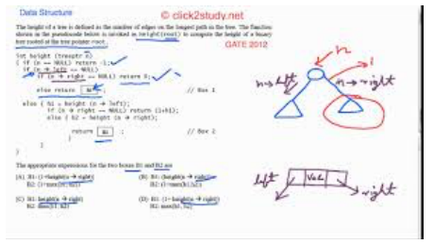


Today's plan

Computational modeling of language acquisition



A brief overview

Language acquisition = Information processing task

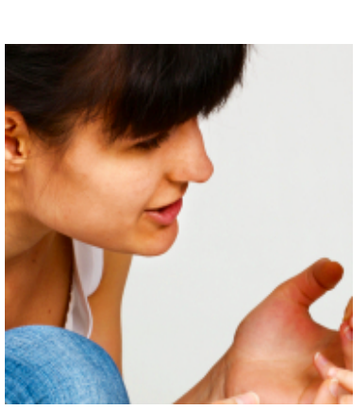
Given the available input …

The penguin tried to climb.

The ice seemed to melt.

Language acquisition = Information processing task

Given the available input, information processing done by human minds…



processing & generalization

The penguin tried to climb.

The ice seemed to melt.

Language acquisition = Information processing task

Given the available input, information processing done by human minds to build a system of linguistic knowledge …

processing & generalization

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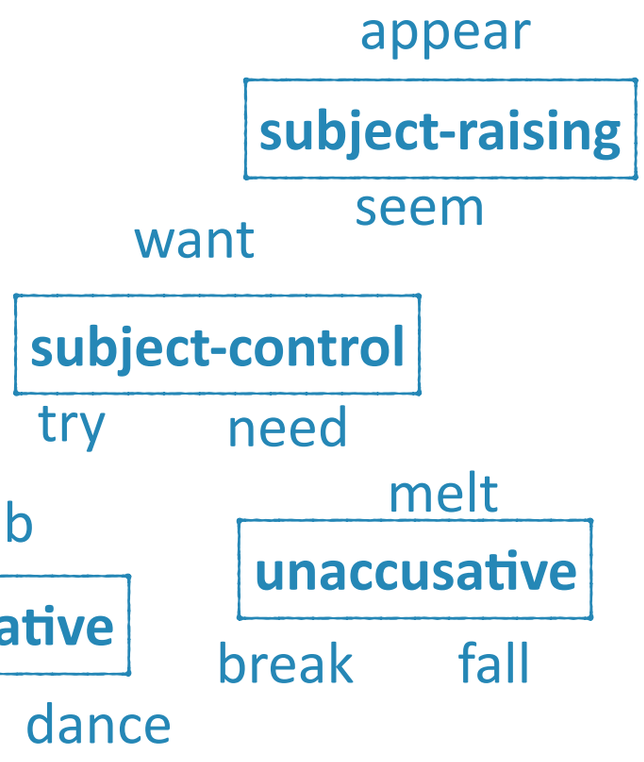
The ice seemed to melt.



Language acquisition = Information processing task

Given the available input, information processing done by human minds to build a system of linguistic knowledge whose output we observe

processing & generalization

appear

subject-raising

seem

want

subject-control

try need

climb

unergative

laugh dance

melt

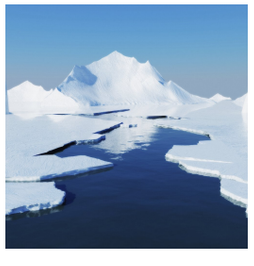
unaccusative

break fall

The penguin tried to climb.

The penguin wanted to dance.

The ice seemed to melt.



It appeared that the ice broke.

Language acquisition = Information processing task

To understand how children solve the acquisition task, we need to make explicit the relevant components of the task.

processing & generalization

appear

subject-raising

seem

want

subject-control

try need

climb

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laugh dance

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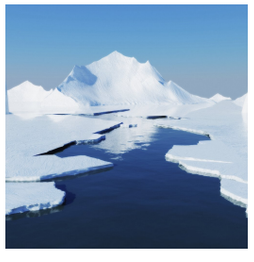
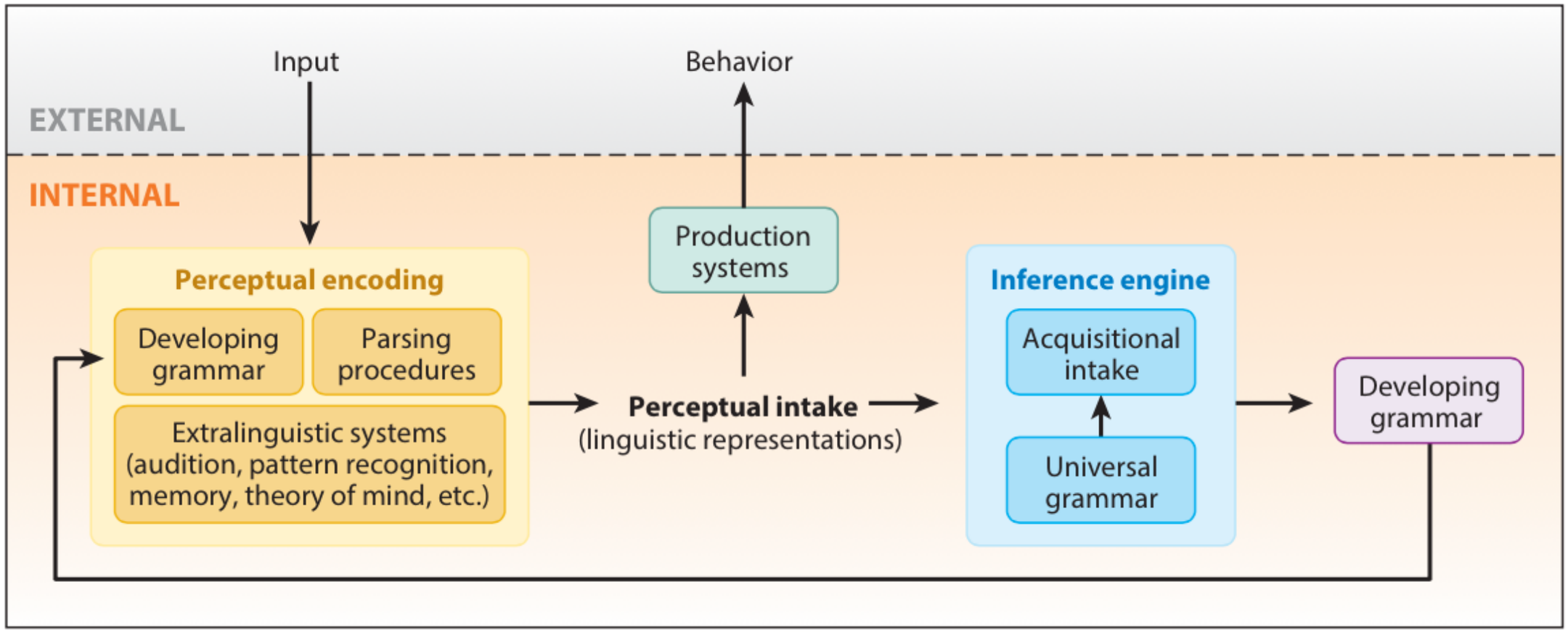


It appeared that the ice broke.

Language acquisition = Information processing task



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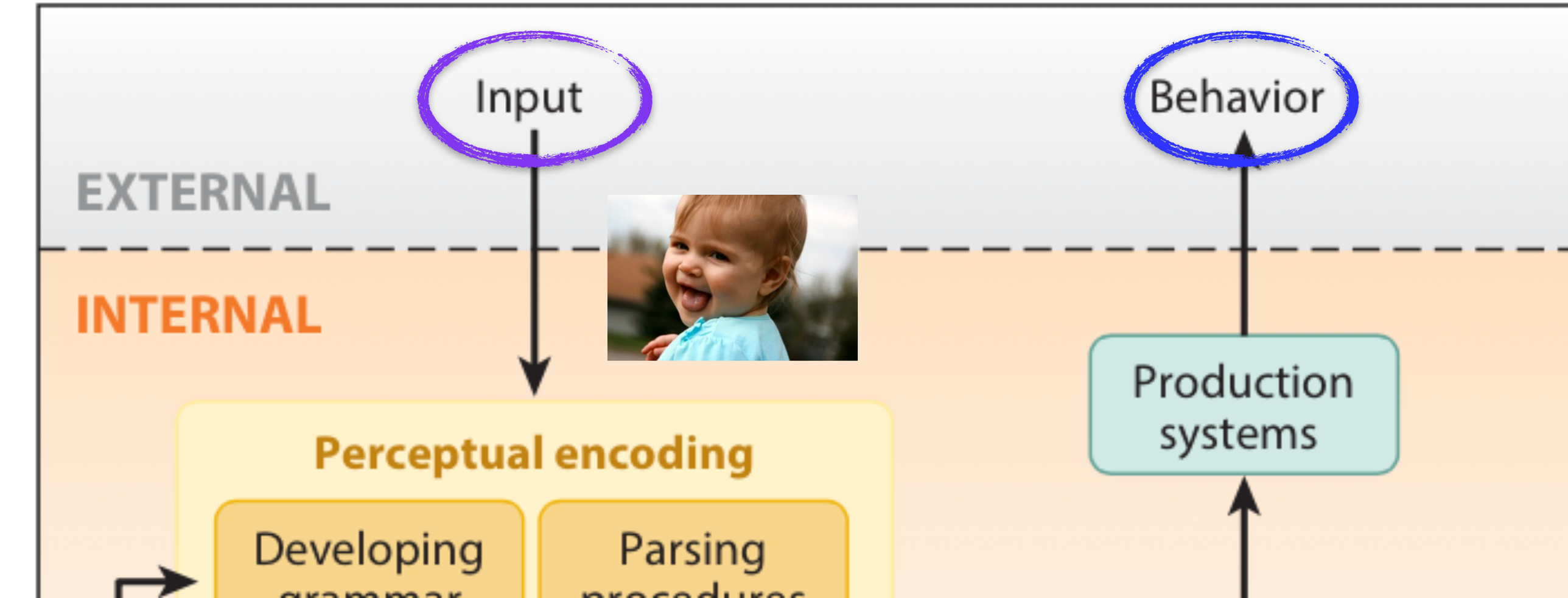
A framework that makes components of the acquisition task more explicit.

A framework that makes components of the acquisition task more explicit.

Distinguishes between things external to the child that we can observe (input signal, child's behavior) vs. things internal to the child (everything else).

Experimental & Corpus methods

Experimental methods



INTERNAL

Perceptual encoding

Developing grammar

Parsing procedures

Extralinguistic systems (audition, pattern recognition, memory, theory of mind, etc.)

Production systems

Perceptual intake (linguistic representations)

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Perceptual encoding:

Turning the input signal into an internal linguistic representation = perceptual intake.

INTERNAL

Theoretical & experimental methods

Perceptual encoding

Developing grammar

Parsing procedures

Extralinguistic systems (audition, pattern recognition, memory, theory of mind, etc.)

Production systems

Perceptual intake
(linguistic representations)

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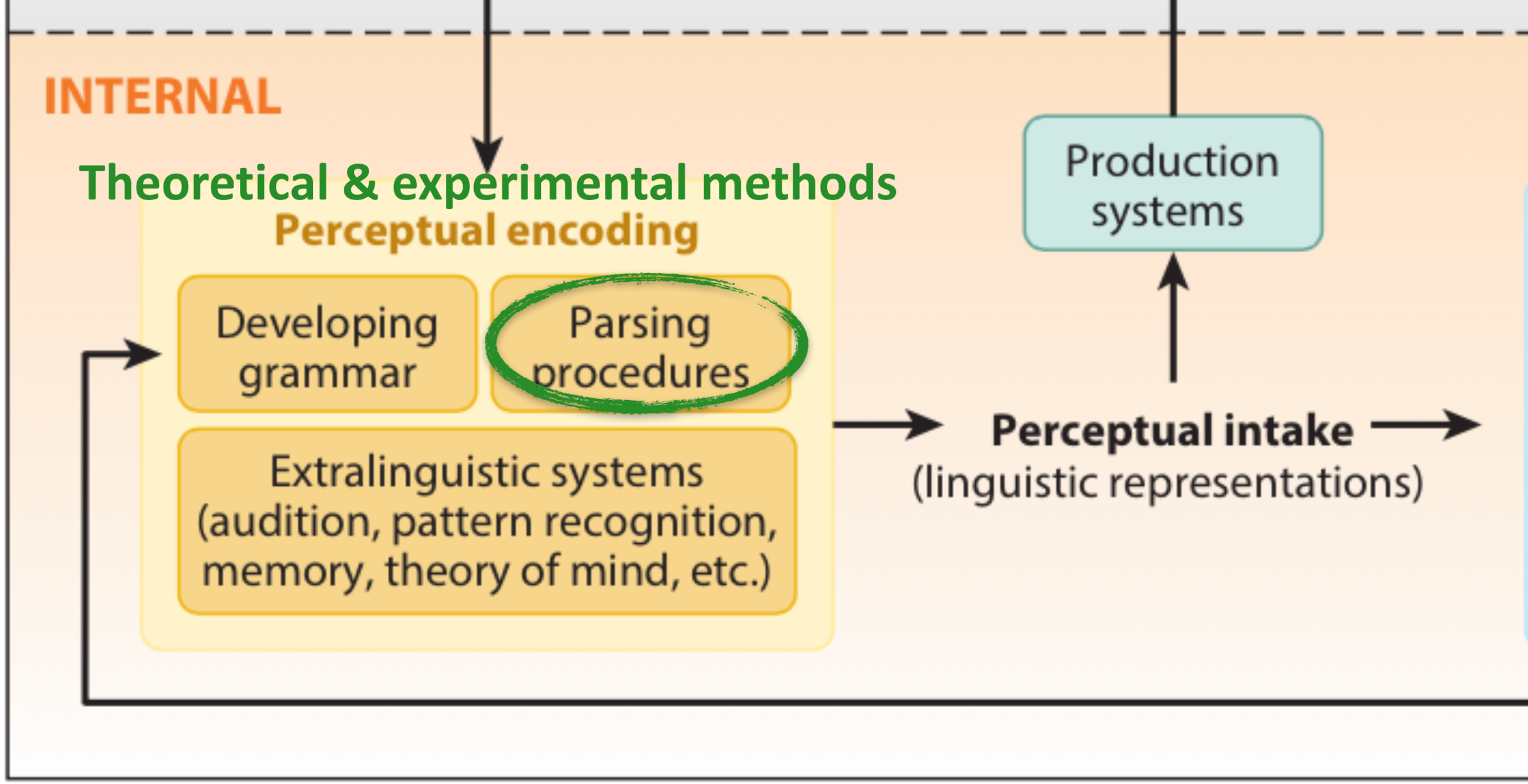
Perceptual encoding:

Involves current grammar



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Perceptual encoding:

Involves current grammar being deployed in real time to parse the input

INTERNAL

Theoretical & experimental methods

Perceptual encoding

Developing grammar

Parsing procedures

Extralinguistic systems (audition, pattern recognition, memory, theory of mind, etc.)

Production systems

Perceptual intake
(linguistic representations)

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Perceptual encoding:

Involves current grammar being deployed in real time to parse the input, often drawing on extralinguistic systems

Input

Behavior

Experimental methods

Production systems

tual encoding

g

Parsing procedures

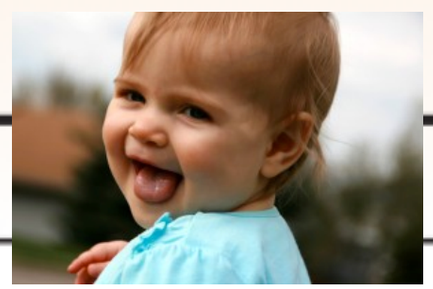
guistic systems
pattern recognition,
heory of mind, etc.)

Perceptual intake
(linguistic representations)

Inference engine

Acquisitional intake

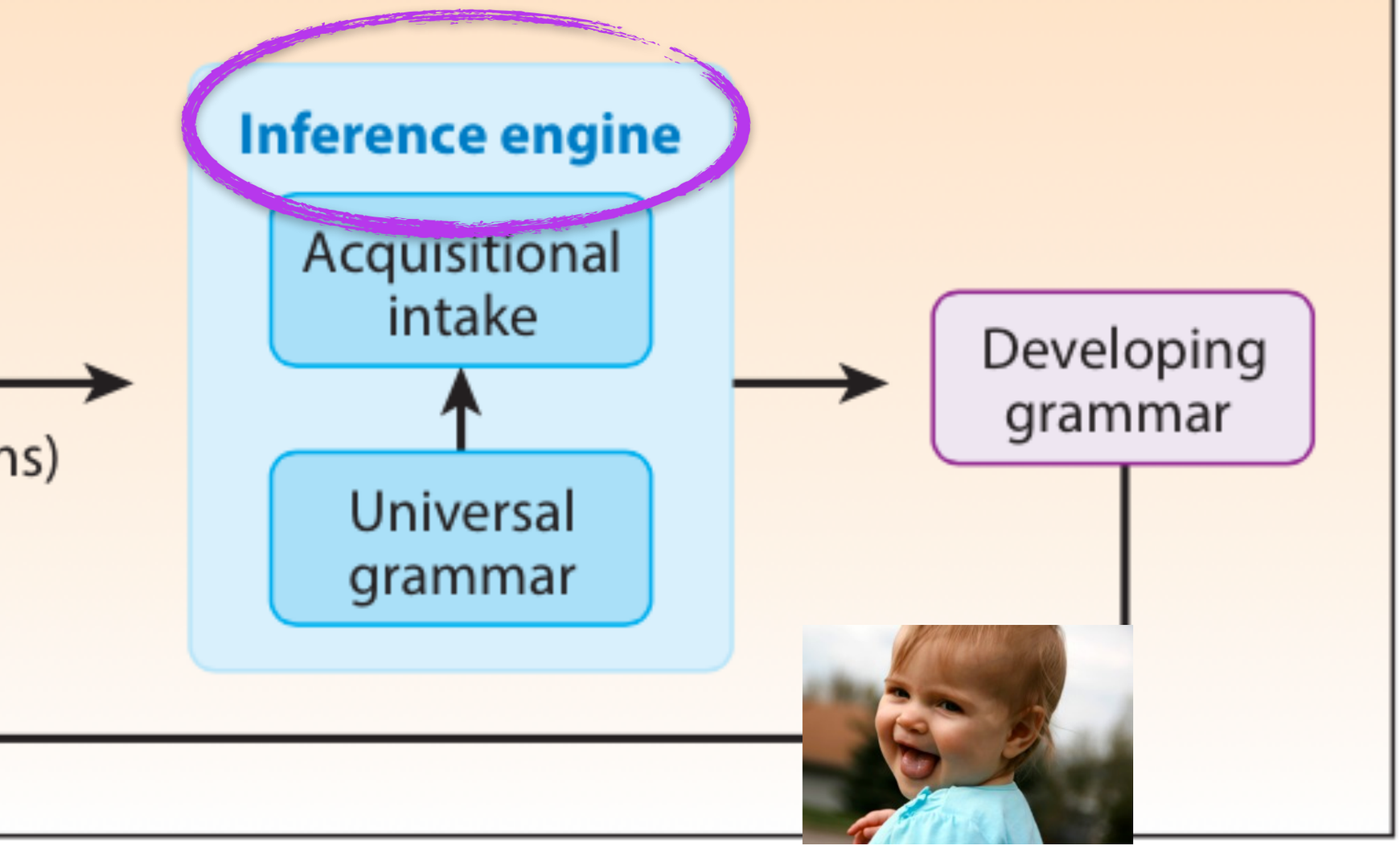
Universal grammar



Generating observable behavior

Involves current linguistic representations being used by production systems.

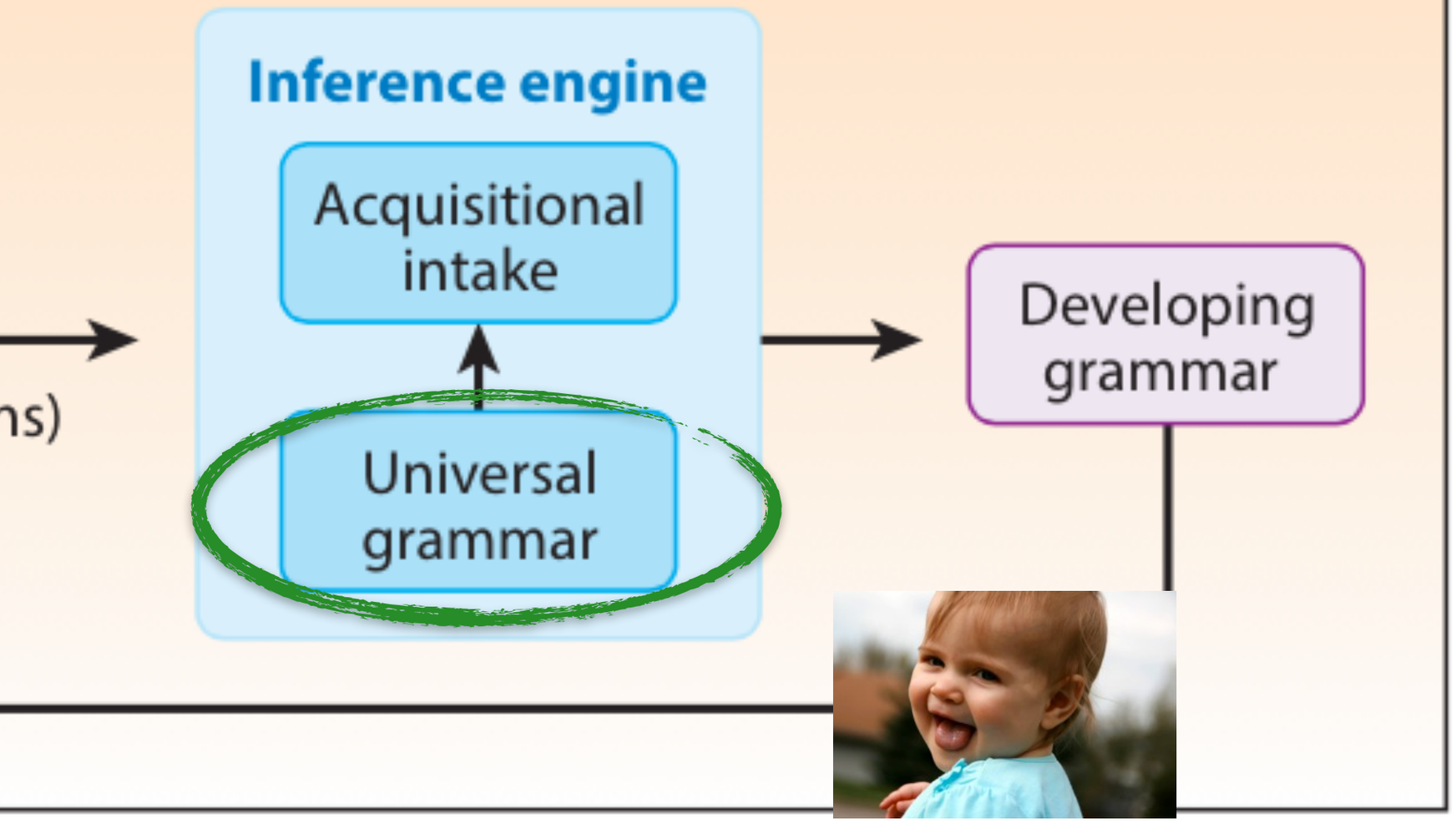
Experimental & computational methods



Doing inference

Generalization happens

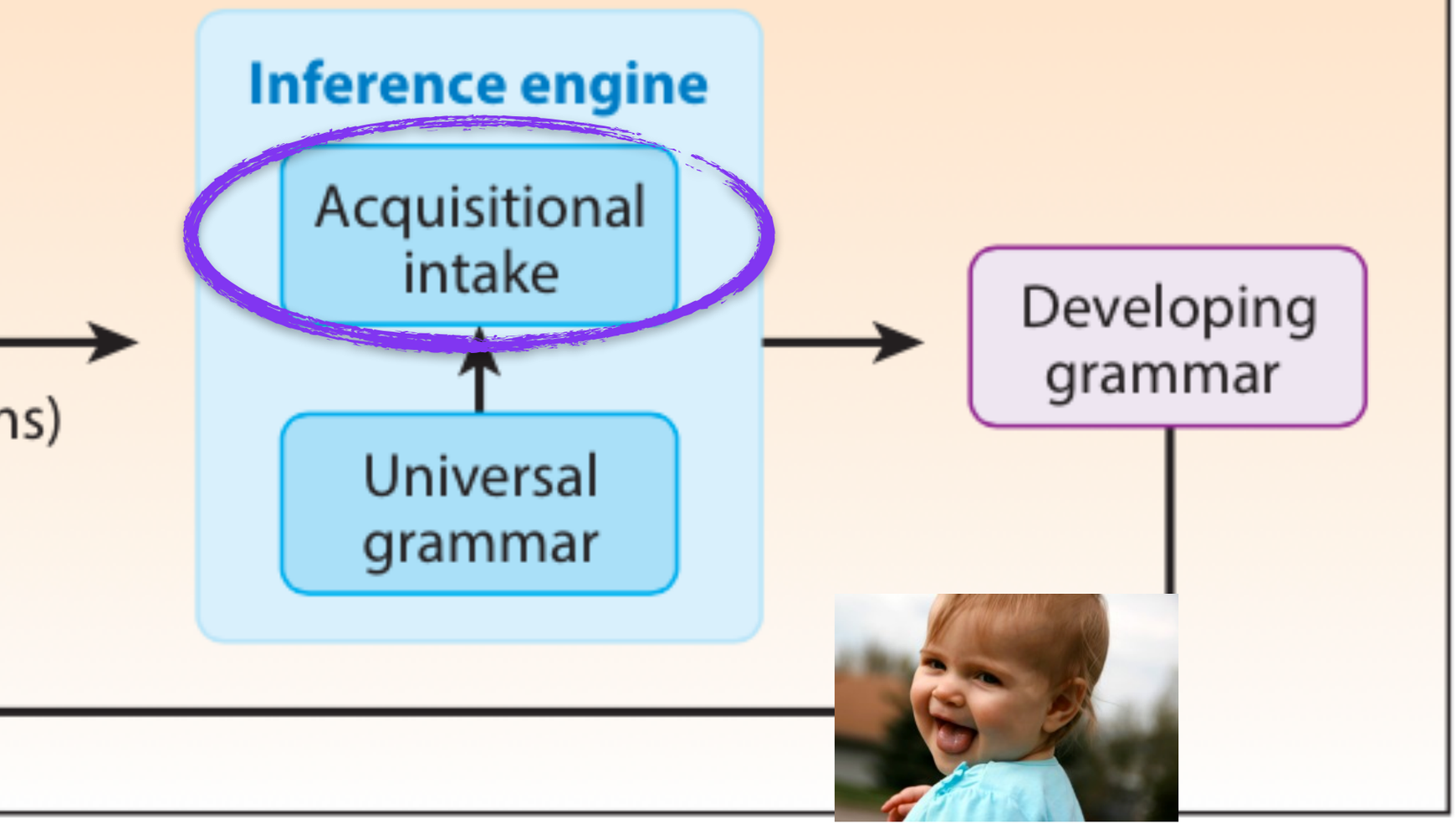
Theoretical & computational methods



Doing inference

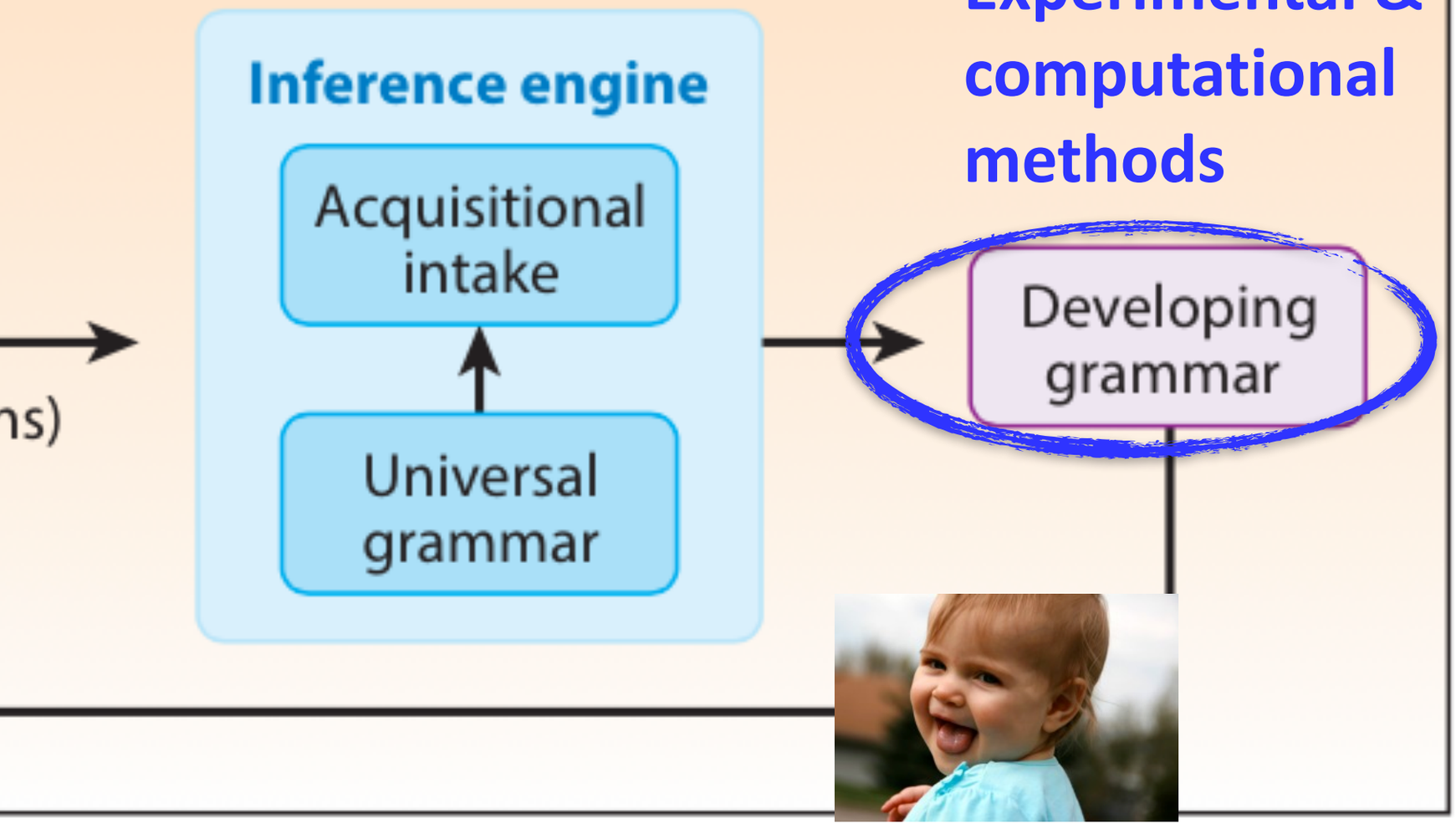
Generalization happens by using existing learning biases, (some of which may be innate and language-specific)

Theoretical & computational methods



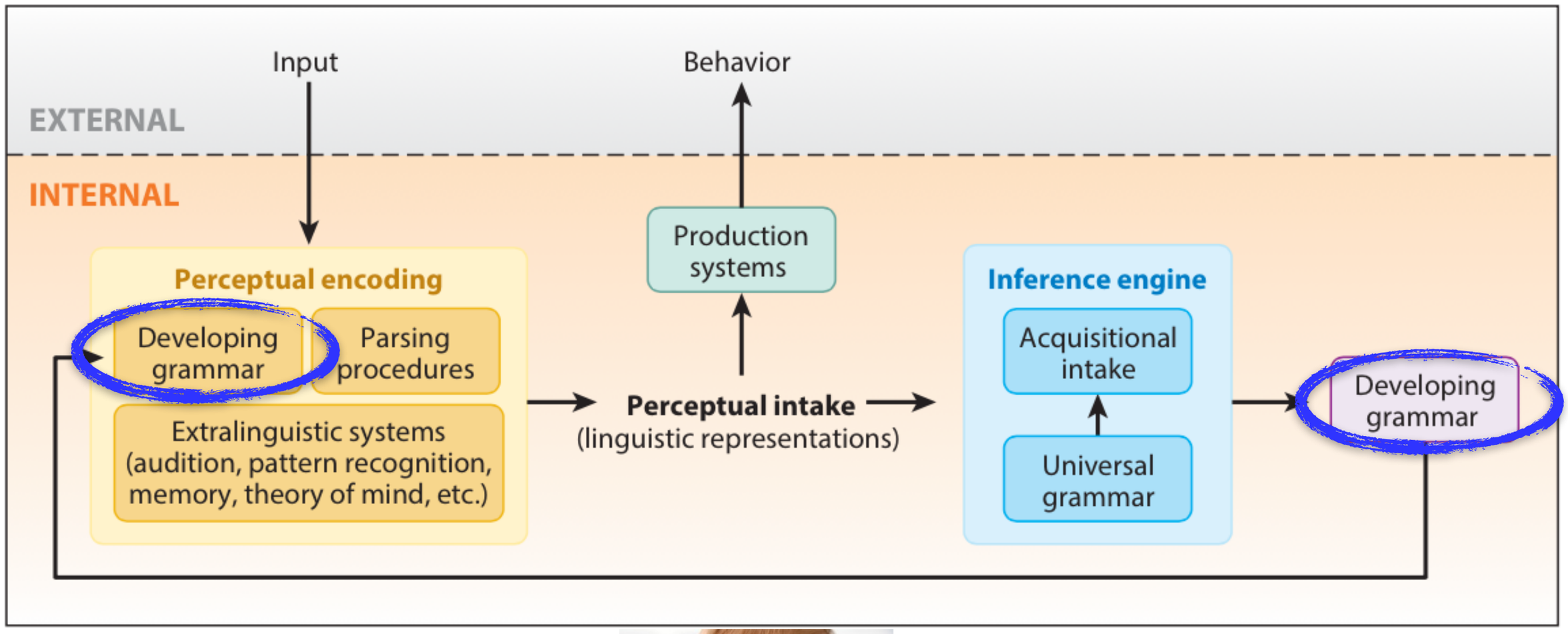
Doing inference

Generalization happens by using existing learning biases, (some of which may be innate and language-specific) operating over the acquisitional intake — what's perceived as relevant for acquisition



Doing inference

Generalization happens by using existing learning biases, (some of which may be innate and language-specific) operating over the acquisitional intake — what's perceived as relevant for acquisition to produce the most up-to-date hypotheses about linguistic knowledge



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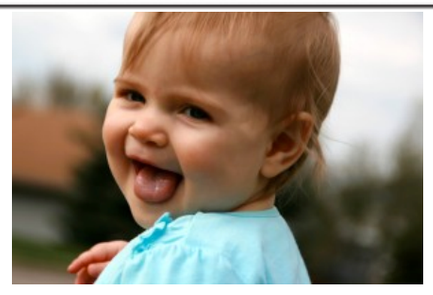
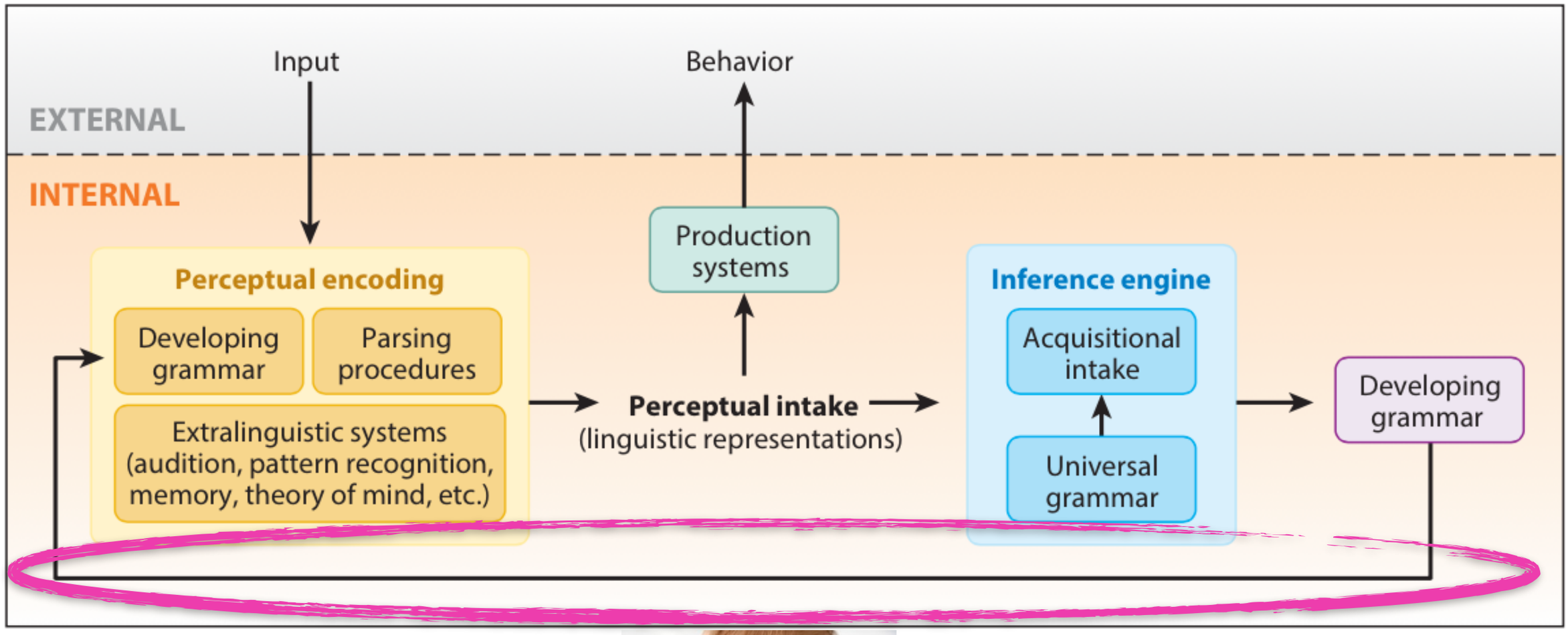


The current linguistic hypotheses are

used in subsequent perceptual encoding



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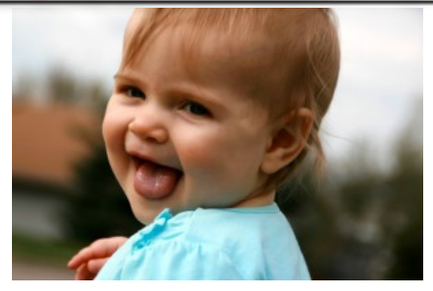
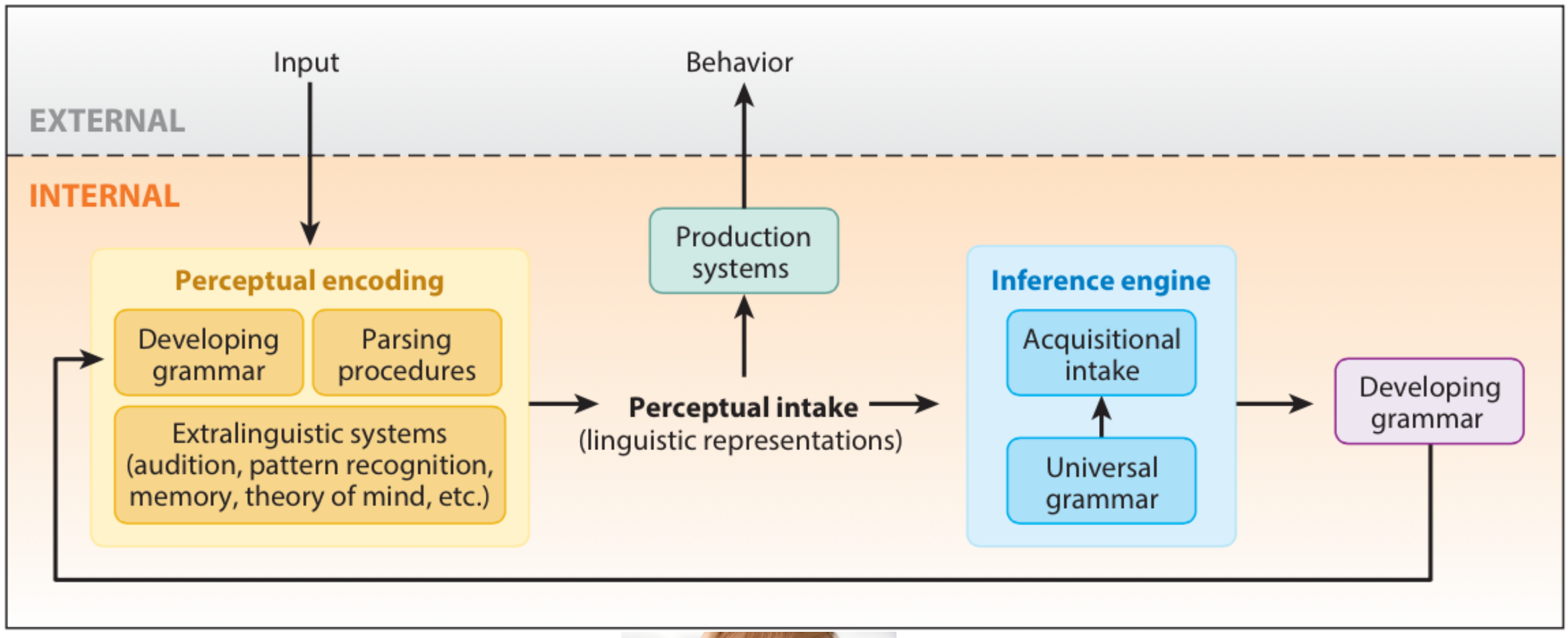


Experimental methods

This whole process **happens over and over again** throughout the **learning period**

This is language acquisition



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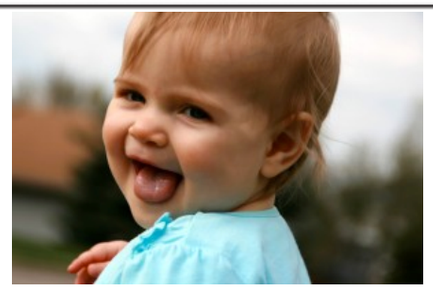
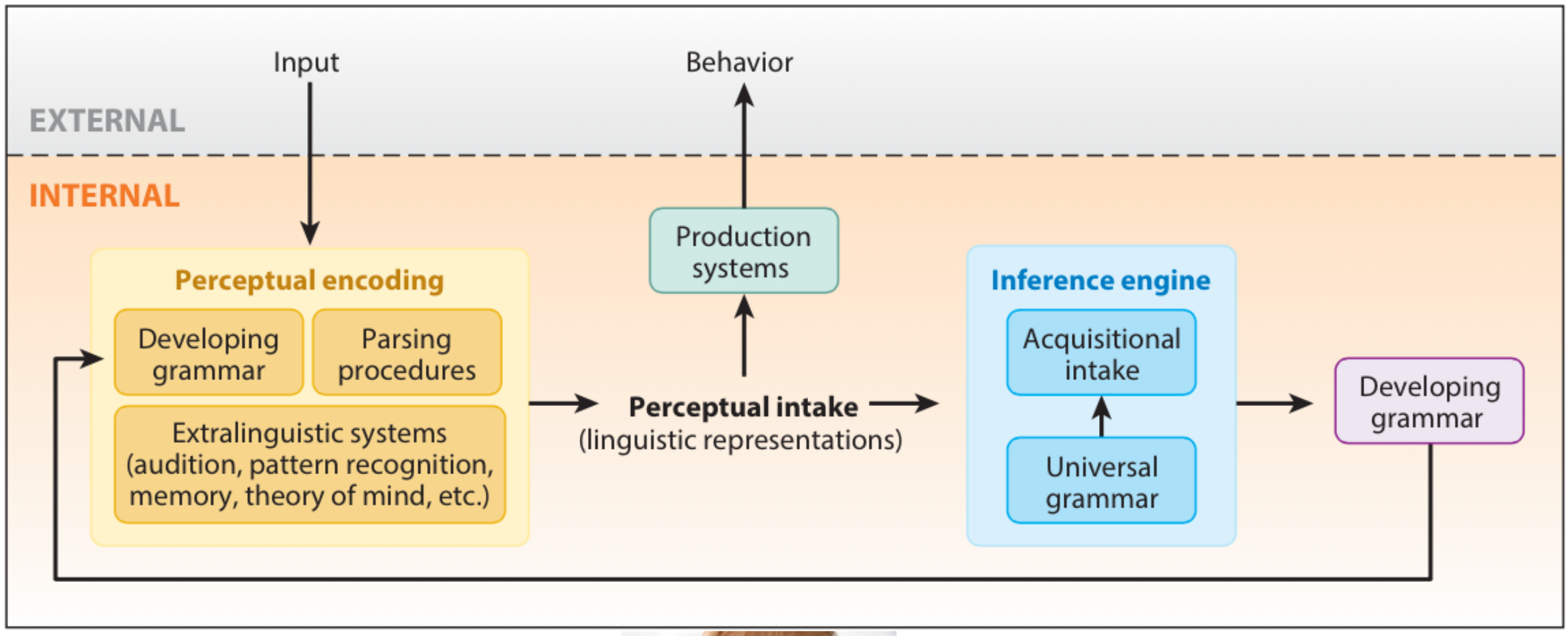


Corpus Experimental

Theoretical Computational

An informative computational model of language acquisition captures these important pieces in an empirically-grounded way.

This is language acquisition



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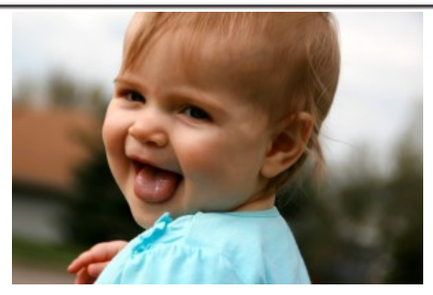
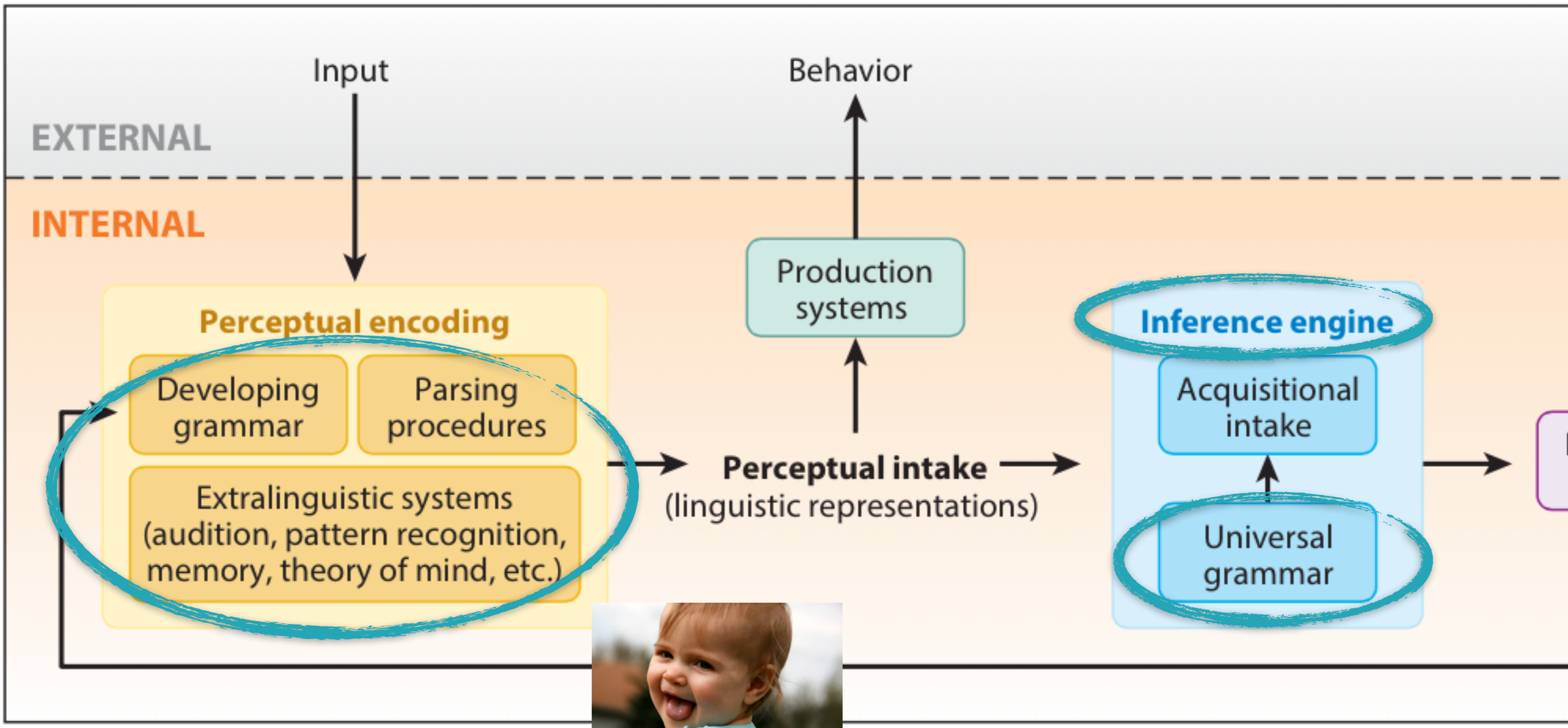


Informative computational models =
informative about the learning strategies children use

Learning strategies children use

A successful learning strategy is an existence proof that linguistic knowledge is attainable using the knowledge, learning biases, and capabilities comprising that strategy.



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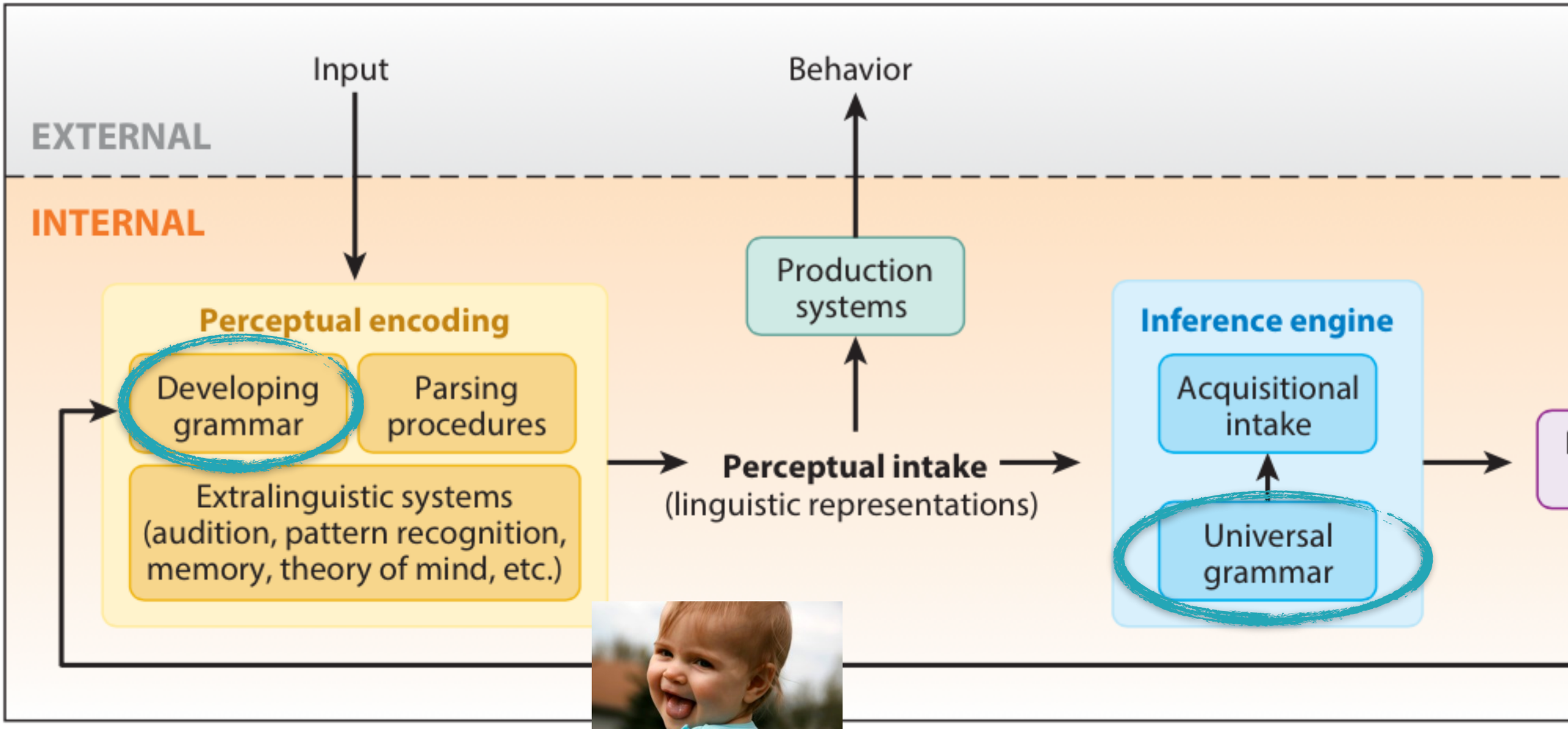
Learning strategies children use

Important learning strategy components include

- knowledge (= theories of **representation**)



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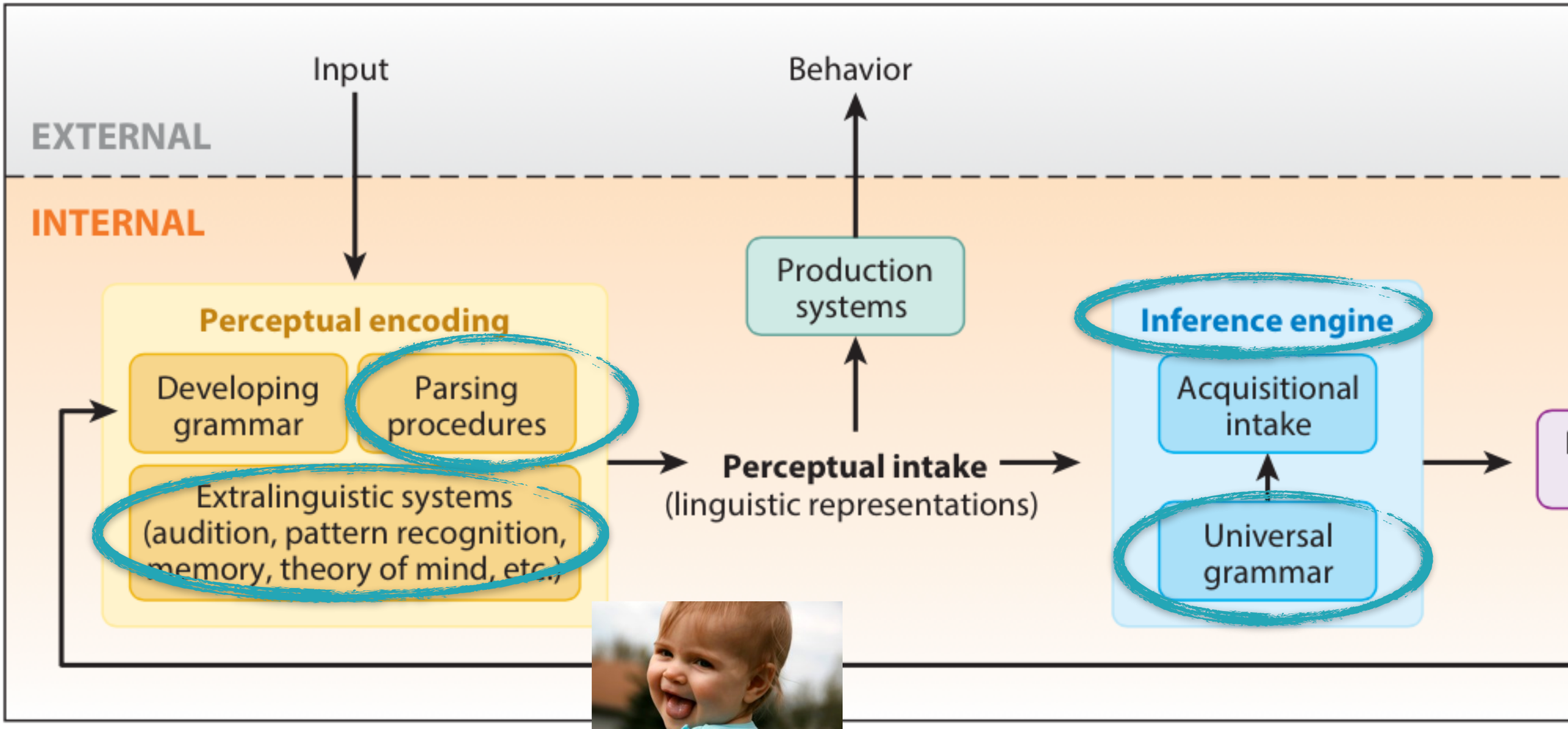
Learning strategies children use

Important learning strategy components include

- theories of **representation**
- biases & capabilities that must exist for that knowledge to be successfully deployed during acquisition (= theories of the **learning process**).



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Learning strategies children use

theories of representation

theories of the learning process

This is what we want to evaluate with computational modeling.

The penguin tried to climb.

The ice seemed to melt.

appear

subject-raising

seem

want

subject-control

try need

climb

unergative

laugh dance

melt

unaccusative

break fall

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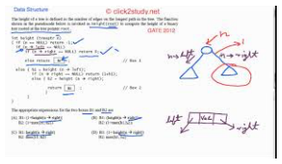
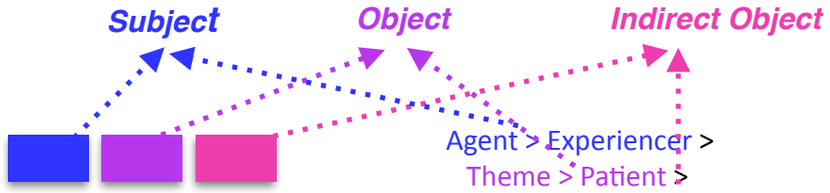
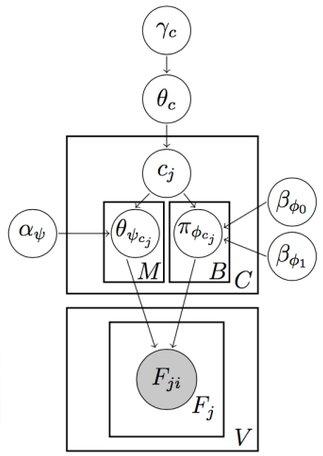
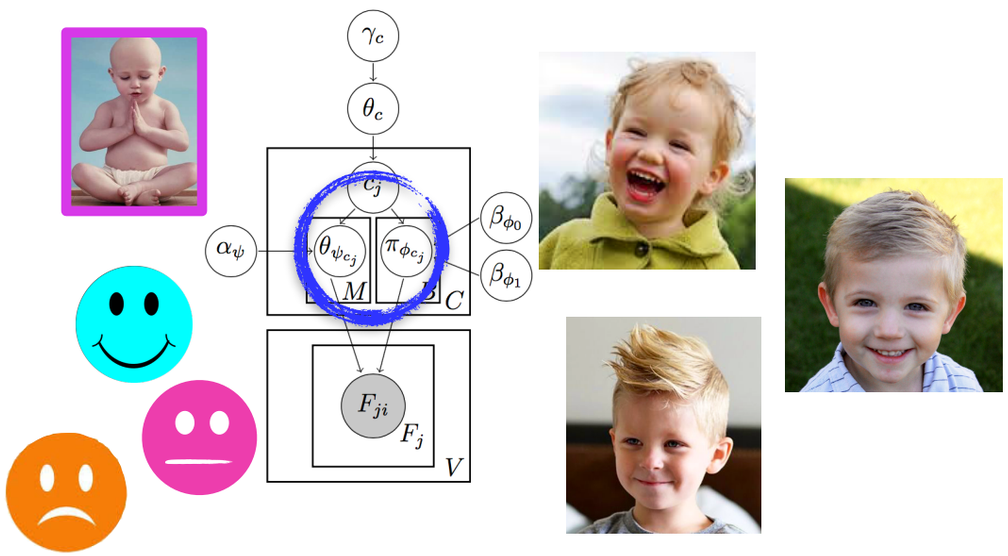
Computational modeling





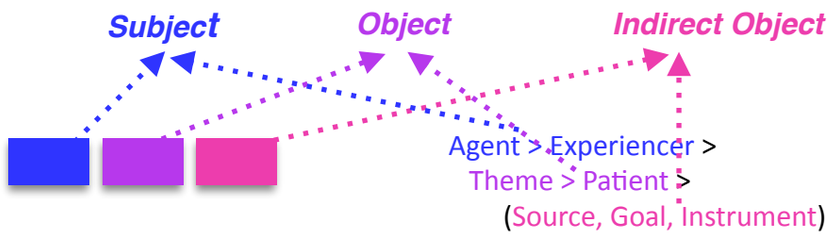


Results & implications



Today's plan

Computational modeling



Information available and how to use it

Information available

The penguin tried to climb.

The ice seemed to melt.

want
subject-control
try need

climb
unergative
laugh dance

appear
subject-raising
seem

melt
unaccusative
break fall

Syntactic cues

Syntactic frame — Shallow “syntactic skeleton” (Gutman et al. 2015)

Children are very adept at using syntactic bootstrapping to learn useful generalizations about how verbs behave (e.g., Fisher et al. 2010, Gutman et al. 2015, Harrigan et al. 2016).

Information available

The ice seemed to melt.

want
subject-control
try need

climb
unergative
laugh dance

appear
subject-raising
seem

melt
unaccusative
break fall

Syntactic cues

Syntactic frame

The penguin **tried** to climb.

NP ___ $S_{nonfinite}$ -surface morphology

NP ___**+past** $S_{nonfinite}$ +surface morphology

Information available

want
subject-control
try need

climb
unergative
laugh dance

appear
subject-raising
seem

melt
unaccusative
break fall

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Conceptual cues

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Information available

melt

climb — **unaccusative**

unergative — break — fall

laugh dance

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Conceptual cues

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Becker 2009, Kirby 2009, Kirby 2010,
Becker 2014, Becker 2015, Hartshorne et al. 2015

appear seem

subject-raising

ask beg

object-raising

It's useful:

It can distinguish verb classes like raising vs. control verbs, and psych object-experiencer verbs.

try want — **subject-control**

believe — **object-control**

need

surprise annoy

psych object-experiencer

worry

Information available

want
subject-control
try need

climb
unergative
laugh dance

appear
subject-raising
seem

melt
unaccusative
break fall

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Conceptual cues

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Becker 2009, Kirby 2009, Kirby 2010,
Becker 2014, Becker 2015, Hartshorne et al. 2015

Children use it:

Young children have been shown to use this cue in experimental studies.

Information available

The penguin tried to climb.

The ice seemed to melt.

want
subject-control
try need

appear
subject-raising
seem

climb
unergative
laugh dance

melt
unaccusative
break fall

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Conceptual cues

Thematic roles

doer = Agent

done-to = Patient

Children could use them:

Thematic roles that indicate event participant roles are salient to very young children.

(<10 months: Gordon 2003; 6 months: Hamlin, Wynn, & Bloom 2007, Hamlin, Wynn, Bloom, & Mahajan 2011)

Information available

Conceptual cues + Syntactic-semantic knowledge

Thematic roles and how to use them

Syntax

She melted **the ice** with **a blow dryer**.

Subject ***Object*** ***Indirect Object***

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

How do we get from here to here?

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**…

Information available

Conceptual cues + Syntactic-semantic knowledge

Thematic roles and how to use them

Syntax **She** melted **the ice** with **a blow dryer**.

Subject ***Object*** ***Indirect Object***

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

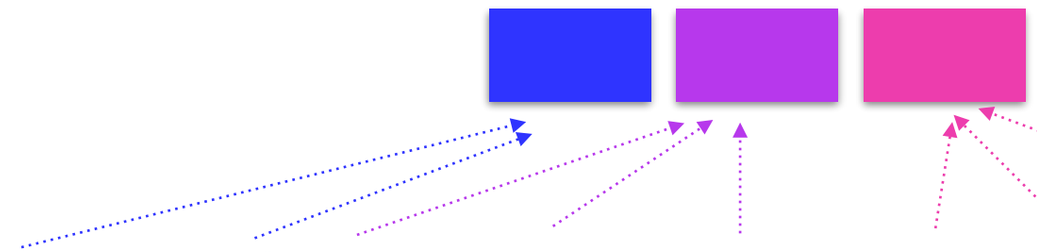
Theories of prior knowledge

Intermediate representations

Thematic roles map to one of three categories.

The **U**niformity of **T**heta **A**ssignment **H**ypothesis

Baker 1988, Baker 1997, Dowty 1991, Fillmore 1968, Grimshaw 1990, Jackendoff 1987, Perlmutter & Postal 1984, Speas 1990



Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**…

Information available

Conceptual cues + Syntactic-semantic knowledge

Thematic roles and how to use them

Syntax

She melted **the ice** with **a blow dryer**.

Subject ***Object*** ***Indirect Object***

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Mapping to Syntax

These categories map to syntactic positions.

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Theories of prior knowledge

Intermediate representations

Thematic roles map to one of three categories.

UTAH

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**…

Information available

Conceptual cues + Syntactic-semantic knowledge

Thematic roles and how to use them

Syntax

She melted **the ice** with **a blow dryer**.

Subject ***Object*** ***Indirect Object***

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Mapping to Syntax

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Theories of prior knowledge

Intermediate representations

UTAH

Thematic roles are ordered with respect to each other.

The (relativized) **UTAH**

Larson 1988, Larson 1990

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**…

Information available

Conceptual cues + Syntactic-semantic knowledge

Thematic roles and how to use them

Syntax

She melted **the ice** with **a blow dryer**.

Subject ***Object*** ***Indirect Object***

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Mapping to Syntax

Whichever ones are present map in order to syntactic positions.

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Theories of prior knowledge

Intermediate representations

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**...

Information available

Conceptual cues + Syntactic-semantic knowledge

Thematic roles and how to use them

Syntax

She melted **the ice** with **a blow dryer**.

Subject ***Object*** ***Indirect Object***

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Standard UTAH and rUTAH implementations typically assume the mapping is also known a priori

Mapping to Syntax

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Theories of prior knowledge

Intermediate representations

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**...

Information available

Conceptual cues + Syntactic-semantic knowledge

Thematic roles and how to use them

Syntax

She melted **the ice** with **a blow dryer**.

Subject ***Object*** ***Indirect Object***

But these are separate components

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Mapping to Syntax

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Theories of prior knowledge

Intermediate representations

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**...

Information available

Conceptual cues + Syntactic-semantic knowledge

Thematic roles and how to use them

Syntax **She** melted **the ice** with **a blow dryer**.

Subject ***Object*** ***Indirect Object***

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Whether children expect a mapping a priori impacts how they perceive the intake for acquisition

Mapping to Syntax

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Theories of prior knowledge

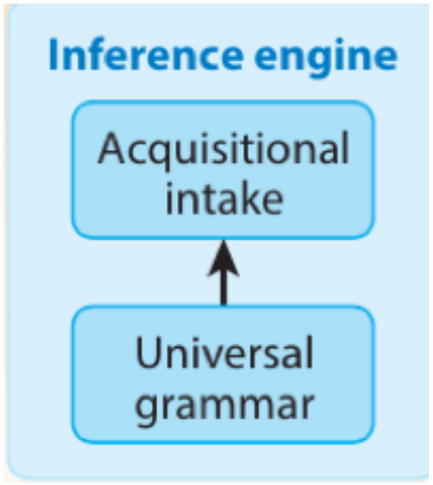
Intermediate representations

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**...



Information available

+expect a mapping

Salient when mapping doesn't hold: Interpreted as movement

Syntax **The ice was melted by the girl.**

Subject — *done-to*

Indirect Object — *doer*

Mapping to Syntax

Theories of prior knowledge

Intermediate representations

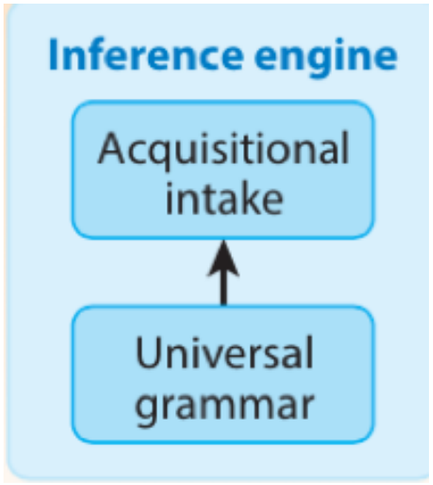
UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Unexpected by UTAH

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**…



Information available

+expect a mapping

Salient when mapping doesn't hold:
Interpreted as movement

melt: +movement

Mapping to Syntax

Theories of prior knowledge

Intermediate representations

Syntax

The ice was melted by the girl.

Subject ***Indirect Object***

2nd highest ***Highest***

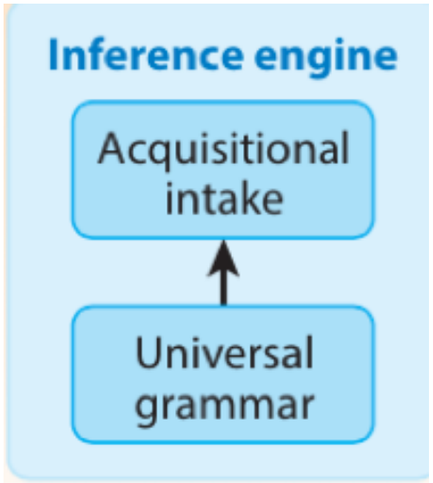
Unexpected by rUTAH

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**…



melt
done-to: Subject
doer: Indirect Object

Information available

-expect a mapping

Children track grammatical positions of intermediate representations

Syntax **The ice was melted by the girl.**

Subject ***Indirect Object***

done-to ***doer***

Mapping to Syntax

Theories of prior knowledge

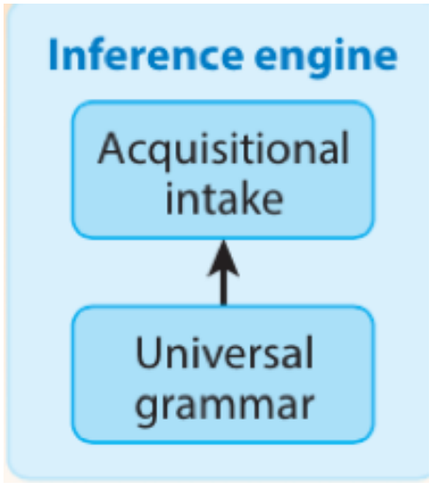
Intermediate representations

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**…



melt
2nd highest: Subject
Highest: Indirect Object

Information available

-expect a mapping

Children track grammatical positions of intermediate representations

Syntax

The ice was melted by the girl.

Subject ***Indirect Object***

2nd highest ***Highest***

Mapping to Syntax

Theories of prior knowledge

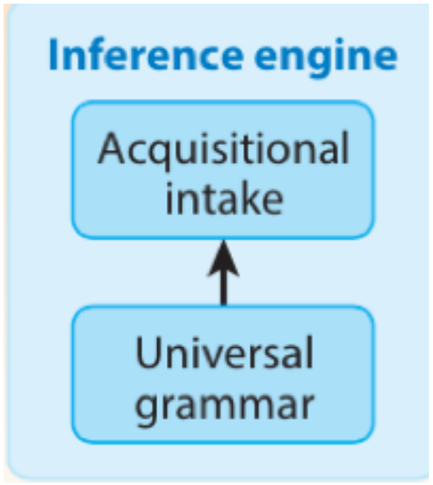
Intermediate representations

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Thematic roles **Agent**, **Experiencer**, **Patient**, **Theme**, **Goal**, **Source**, **Instrument**…



Information available

Conceptual cues + Syntactic-semantic knowledge

Thematic roles and how to use them

Syntax **The ice was melted by the girl.**

Subject ***Indirect Object***

Mapping to Syntax **+expmap** **-expmap**

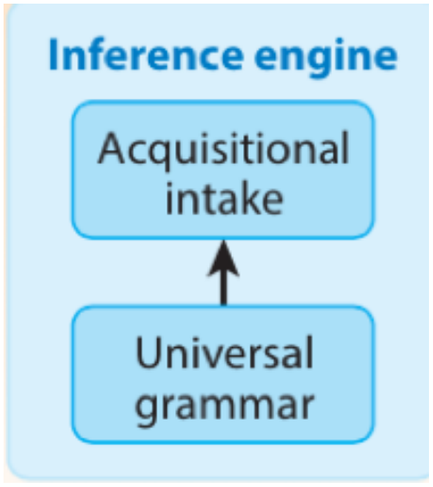
Intermediate representations

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Thematic roles **Agent, Experiencer, Patient, Theme, Goal, Source, Instrument…**



Information available

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Animacy

+animate

The penguin tried to climb.

-animate

The ice seemed to melt.

Thematic roles and how to use them

UTAH -expmap

Subject ***Object*** ***Indirect Object***

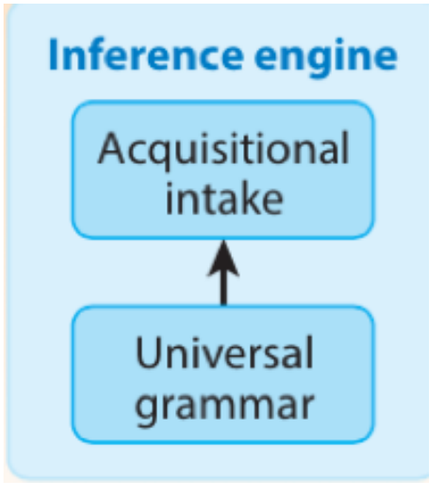
Agent > Experiencer > Theme > Patient >

(Source, Goal, Instrument)

rUTAH +expmap

Subject ***Object*** ***Indirect Object***

movement?



Potential learning strategies

Animacy

+animate
The penguin tried to climb.

-animate
The ice seemed to melt.

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Thematic roles and how to use them

UTAH -expmap

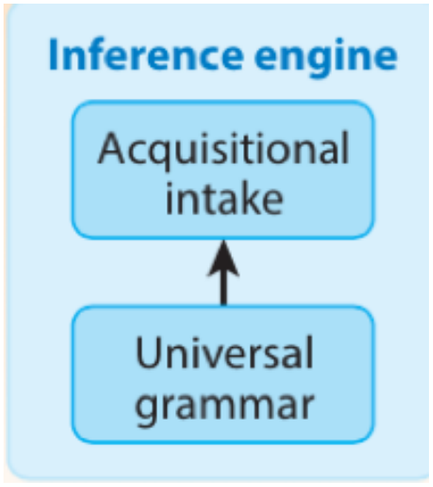
Subject ***Object*** ***Indirect Object***

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

rUTAH +expmap

Subject ***Object*** ***Indirect Object***

movement?



Potential learning strategies

Animacy

+animate
The penguin tried to climb.

-animate
The ice seemed to melt.

Syntactic frame

Choice 1

NP ___ $S_{nonfinite}$ -surfmorph

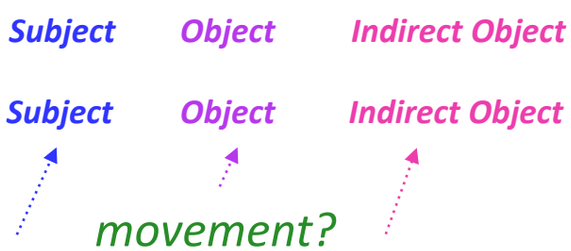
NP ___**+past** $S_{nonfinite}$ +surfmorph

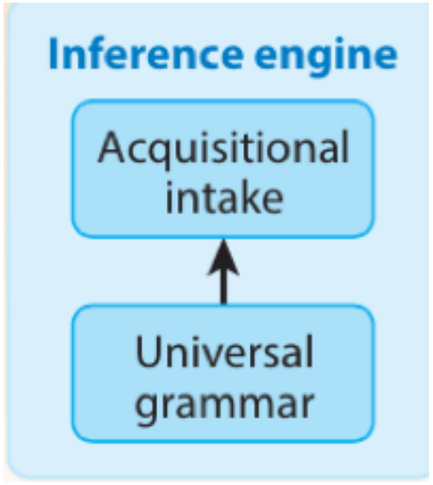
Thematic roles and how to use them

UTAH -expmap

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

rUTAH +expmap





Potential learning strategies

Choice 1

Animacy

+animate
The penguin tried to climb.

-animate
The ice seemed to melt.

Syntactic frame

NP ___ $S_{nonfinite}$ -surfmorph
NP ___**+past** $S_{nonfinite}$ +surfmorph

Thematic roles and how to use them

UTAH

Choice 2

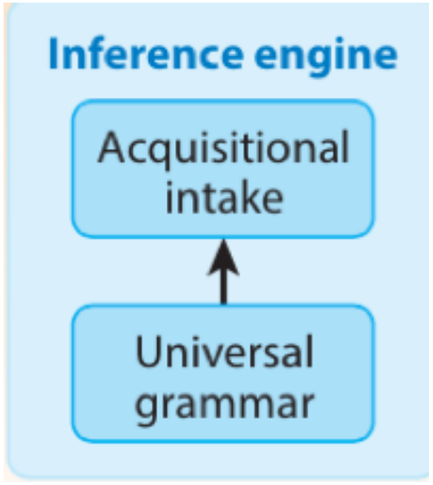
rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

-expmap ***Subject*** ***Object*** ***Indirect Object***

+expmap ***Subject*** ***Object*** ***Indirect Object***

movement?



Potential learning strategies

Animacy

+animate
The penguin tried to climb.

-animate
The ice seemed to melt.

Syntactic frame

Choice 1

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Thematic roles and how to use them

Choice 2

UTAH

Agent > Experiencer > rUTAH
Theme > Patient >
(Source, Goal, Instrument)

Choice 3

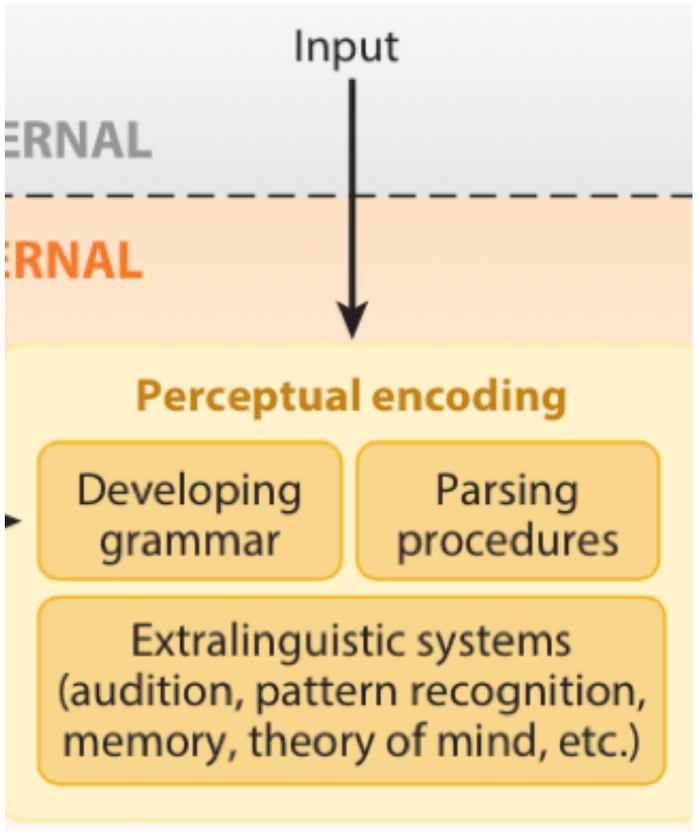
Subject ***Object*** ***Indirect Object*** -expmap

Subject ***Object*** ***Indirect Object*** +expmap

movement?

3 binary choices = 8 strategies

Potential learning strategies



Animacy

+animate
The penguin tried to climb.

-animate
The ice seemed to melt.

Syntactic frame

Choice 1

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph

Thematic roles and how to use them

UTAH

Choice 2

Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)

rUTAH

Choice 3

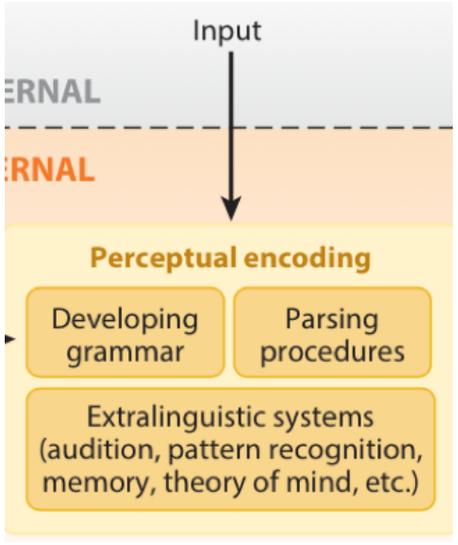
Subject ***Object*** ***Indirect Object*** -expmap

Subject ***Object*** ***Indirect Object*** +expmap

movement?

3 binary choices = 8 strategies

All strategies require learner's initial state to be sufficient to extract this information from the input



Potential acquisitional intakes

3 binary choices = 8 strategies

Each strategy has a different impact on the acquisitional intake

Animacy

Syntactic frame

-surfmorph +surfmorph

Thematic roles and how to use them

UTAH rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

-expmap +expmap

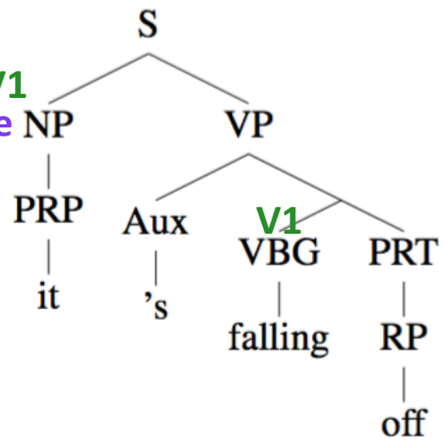
Subject Object Indirect Object ***Subject Object Indirect Object***

movement?

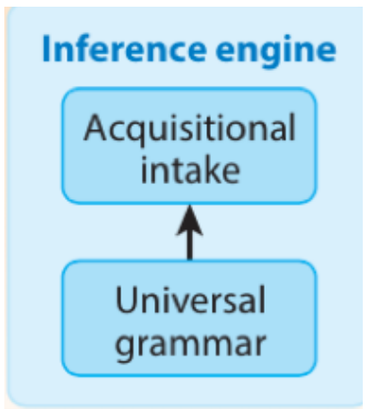
Input

(from Brown-Eve corpus in CHILDES Treebank)

subject
Theme-V1
-animate



Possible perceptual intake



Potential acquisitional intakes

3 binary choices = 8 strategies

Each strategy has a different impact on the acquisitional intake

Animacy

Syntactic frame

-surfmorph +surfmorph

Thematic roles and how to use them

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

-expmap

Subject Object Indirect Object

+expmap

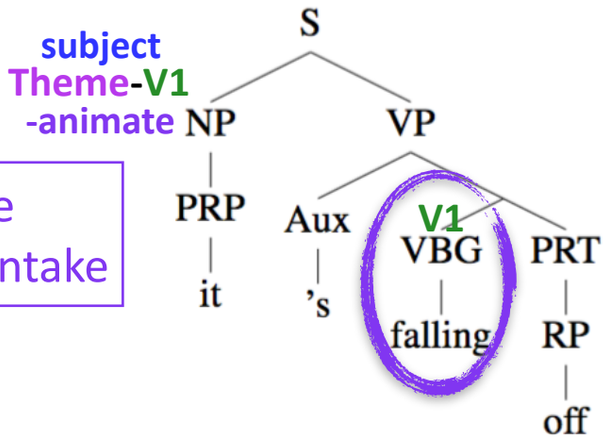
Subject Object Indirect Object

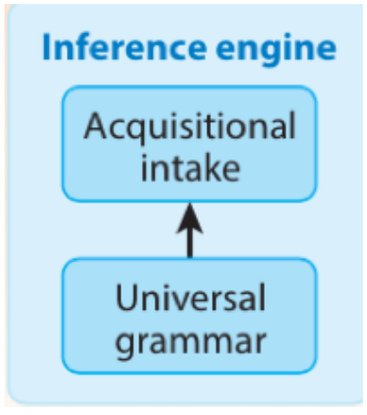
movement?

“it’s falling off”

Input

Possible perceptual intake





FALL

Potential acquisitional intakes

3 binary choices = 8 strategies

Each strategy has a different impact on the acquisitional intake

Animacy

Syntactic frame

-surfmorph +surfmorph

Thematic roles and how to use them

UTAH

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

-expmap

Subject Object Indirect Object

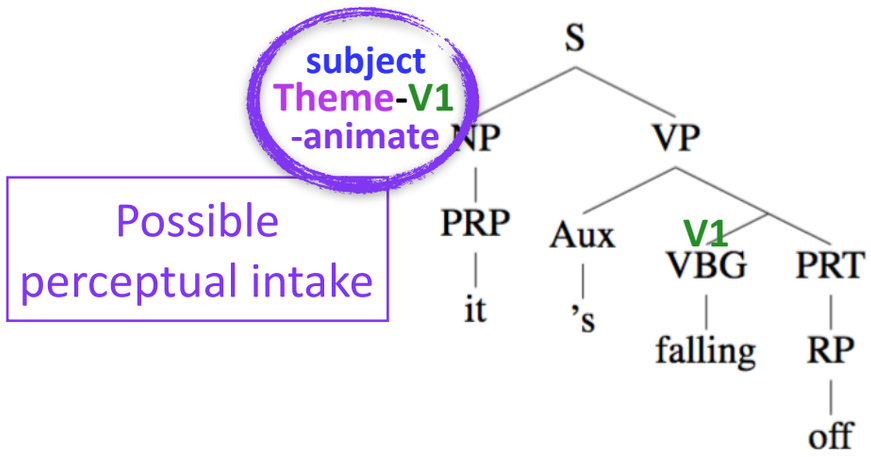
+expmap

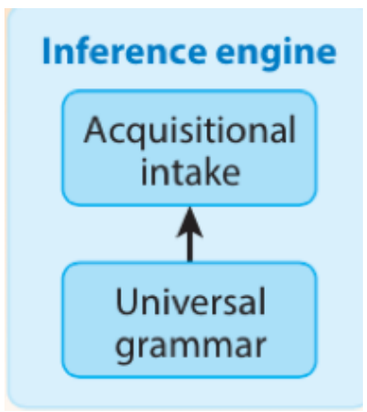
Subject Object Indirect Object

movement?

“it’s falling off”

Input





FALL

-animate subject: 1

Potential acquisitional intakes

3 binary choices = 8 strategies

Each strategy has a different impact on the acquisitional intake

Animacy

Syntactic frame

+surfmorph

Thematic roles and how to use them

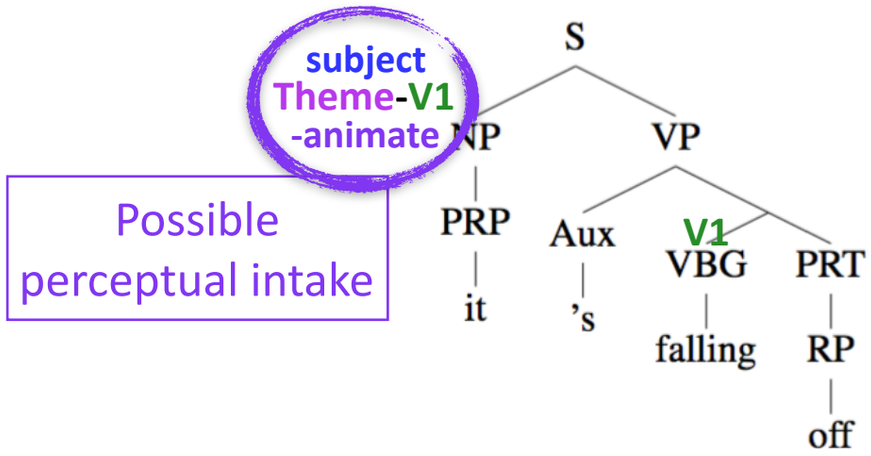
rUTAH

Agent > Experiencer >

Theme > Patient >

(Source, Goal, Instrument)

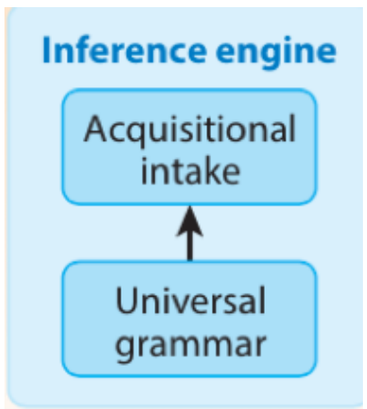
+expmap



Subject ***Object*** ***Indirect Object***

Subject ***Object*** ***Indirect Object***

movement?



FALL

-animate subject: 1

Done-to as subject: 1

UTAH

-expmap

-surfmorph

Potential acquisitional intakes

3 binary choices = 8 strategies

Each strategy has a different impact on the acquisitional intake

Animacy

Syntactic frame

+surfmorph

Thematic roles and how to use them

rUTAH

Agent > Experiencer >

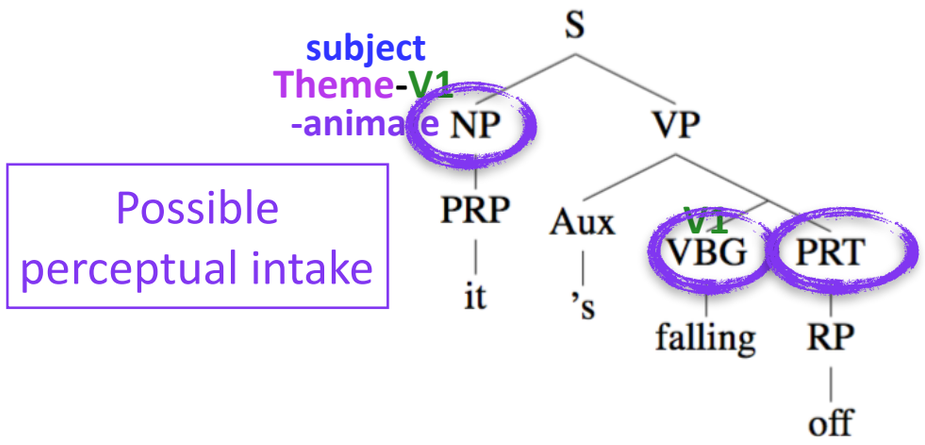
Theme > Patient >

(Source, Goal, Instrument)

+expmap

“it’s falling off”

Input

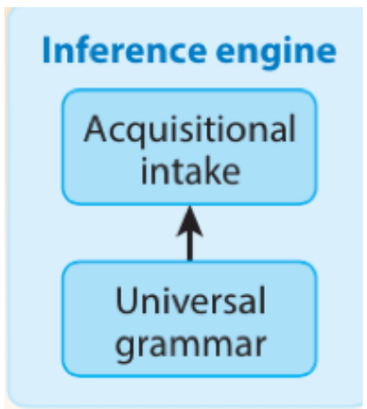


Possible perceptual intake

Subject Object Indirect Object

Subject Object Indirect Object

movement?



FALL

-animate subject: 1

Done-to as subject: 1

NP V PRT

UTAH

-expmap

-surfmorph

Potential acquisitional intakes

3 binary choices = 8 strategies

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rUTAH

Agent > Experiencer >

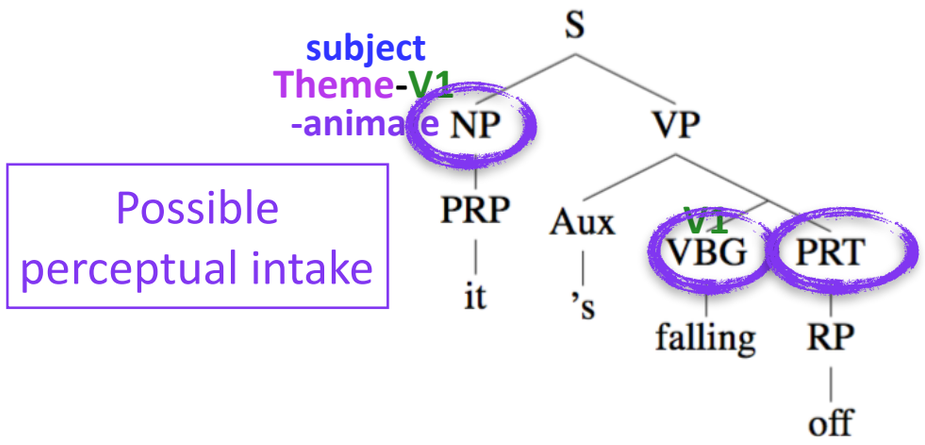
Theme > Patient >

(Source, Goal, Instrument)

+expmap

“it’s falling off”

Input

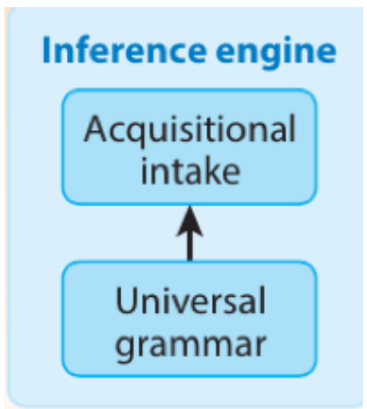


Possible perceptual intake

Subject Object Indirect Object

Subject Object Indirect Object

movement?



FALL

-animate subject: 1

Done-to as subject: 1

NP V_{+prog} PRT

UTAH

-expmap

+surfmorph

Potential acquisitional intakes

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Theme > Patient >

(Source, Goal, Instrument)

-expmap

Subject Object Indirect Object

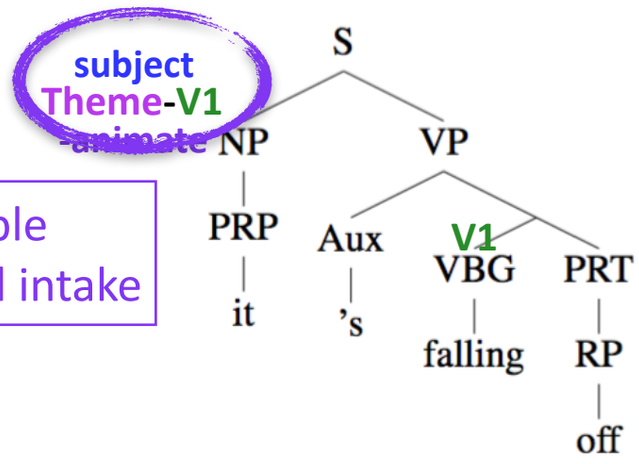
Subject Object Indirect Object

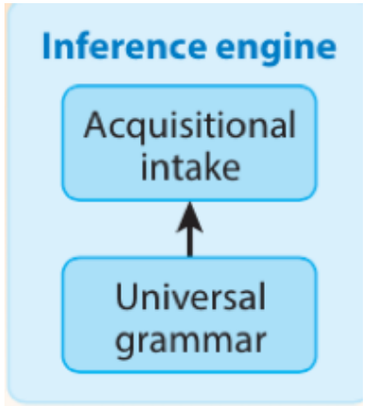
movement?

Input

"it's falling off"

Possible perceptual intake





Theme is expected to map to object, not subject. Indicator of movement.

FALL

-animate subject: 1

+movement: 1

NP V_{+prog} PRT

UTAH

+expmap

+surfmorph

Potential acquisitional intakes

3 binary choices = 8 strategies

Each strategy has a different impact on the acquisitional intake

Animacy

Syntactic frame

-surfmorph

Thematic roles and how to use them

UTAH

-expmap

Subject Object Indirect Object

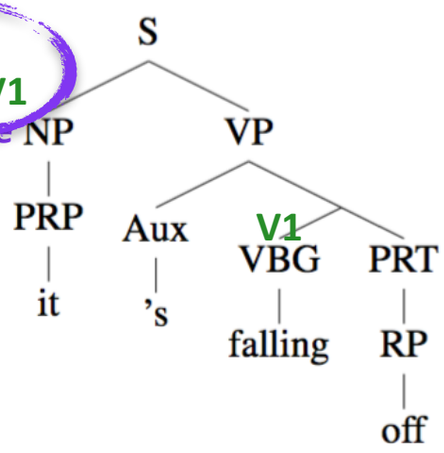
Subject Object Indirect Object

movement?

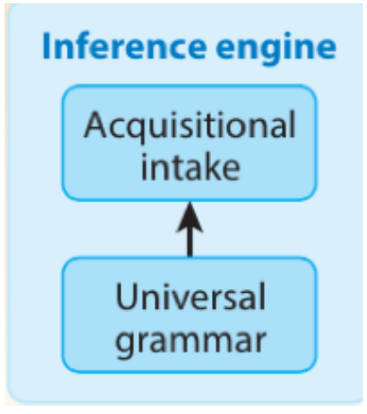
“it’s falling off”

Input

subject
Theme-V1
~~-animate~~



Possible perceptual intake



Theme is only role so is default highest. Expected mapping is to highest syntactic position (subject).

FALL

-animate subject: 1

+movement: 0

NP V_{+prog} PRT

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

+expmap

+surfmorph

Potential acquisitional intakes

“it’s falling off”

Input

3 binary choices = 8 strategies

Each strategy has a different impact on the acquisitional intake

Animacy

Syntactic frame

-surfmorph

Thematic roles and how to use them

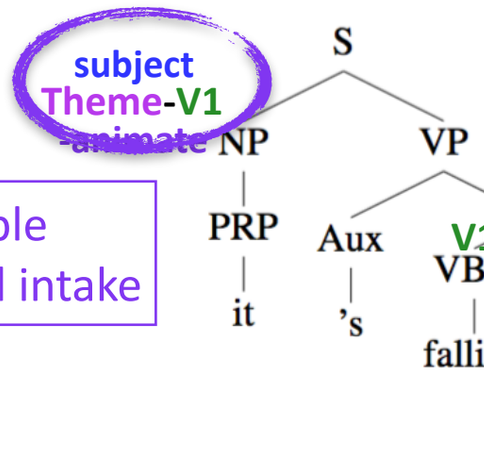
UTAH

+expmap

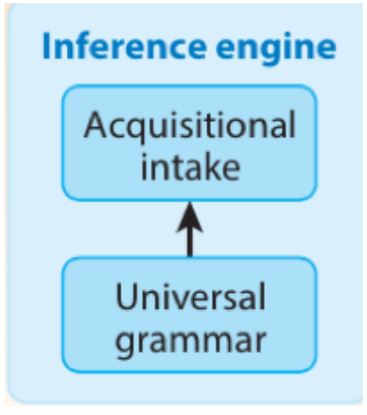
Subject Object Indirect Object

Subject Object Indirect Object

movement?



Possible perceptual intake



FALL

-animate subject: 1

Highest role as subject: 1

NP V_{+prog} PRT

rUTAH

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

-expmap

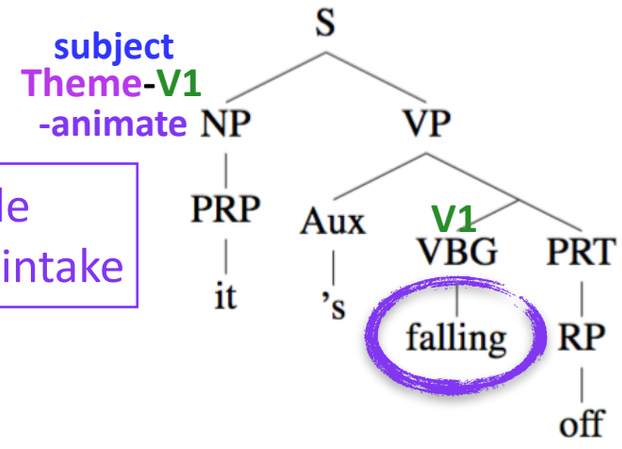
+surfmorph

8 modeled learners and their acquisitional intakes

“it’s falling off”

Input

Possible perceptual intake



FALL

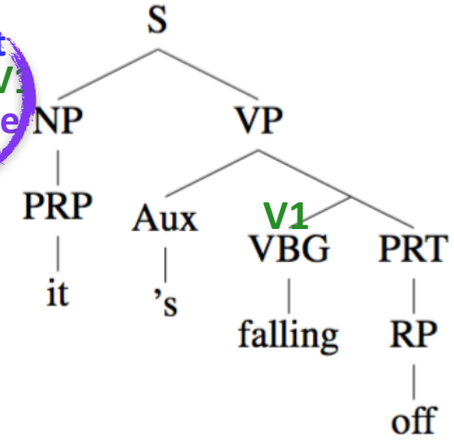
8 modeled learners and their acquisitional intakes

"it's falling off"

Input

subject
Theme-V1
-animate

Possible perceptual intake



FALL

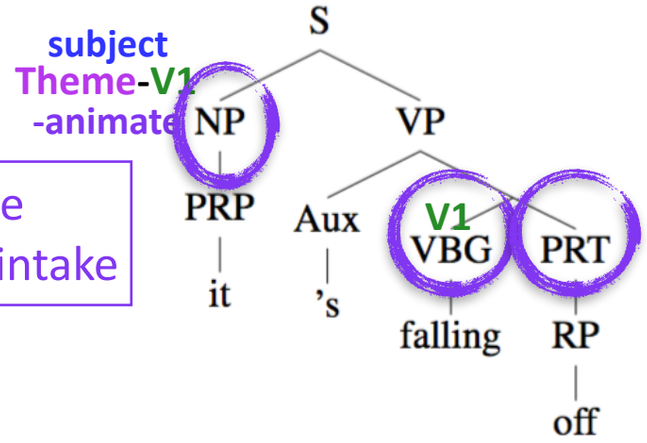
Animacy -animate subject: 1 **All 8 learners**

8 modeled learners and their acquisitional intakes

"it's falling off"

Input

Possible perceptual intake



FALL

Animacy: -animate subject: 1 — All 8 learners

Syntactic frame

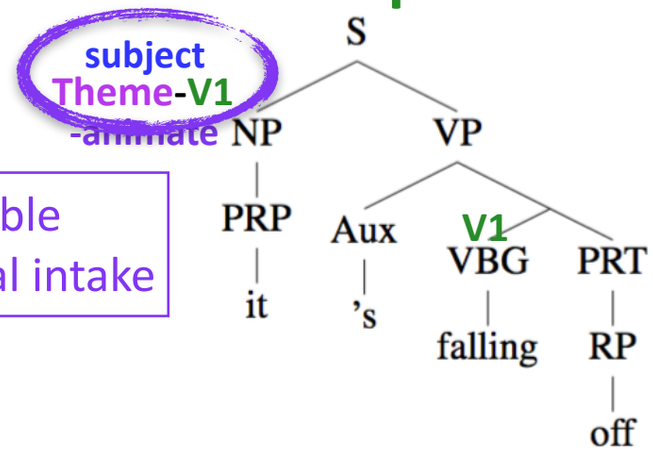
-surfmorph	+surfmorph
4 learners	**4 learners**
NP V PRT	NP V_{+prog} PRT

8 modeled learners and their acquisitional intakes

Input

"it's falling off"

Possible perceptual intake



FALL

Animacy: -animate subject: 1 — All 8 learners

Syntactic frame: -surfmorph — 4 learners — NP V PRT

+surfmorph — 4 learners — NP V_{+prog} PRT

Intermediate representation

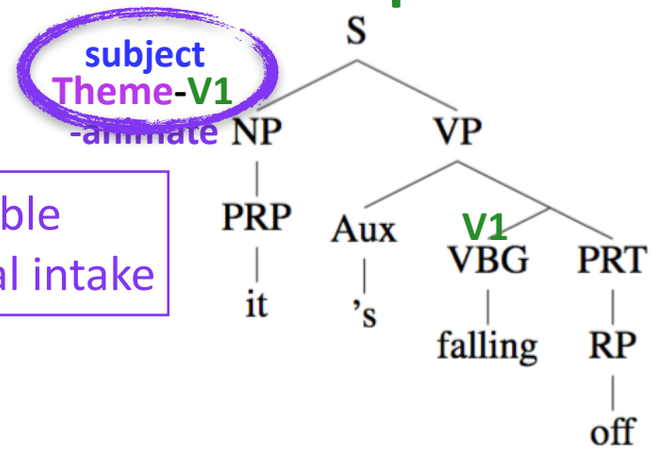
-surfmorph		+surfmorph	
UTAH	rUTAH	UTAH	rUTAH
Done-to as *subject*	*Highest* as *subject*	*Done-to* as *subject*	*Highest* as *subject*
2 learners	**2 learners**	**2 learners**	**2 learners**

8 modeled learners and their acquisitional intakes

"it's falling off"

Input

Possible perceptual intake



FALL

Animacy: -animate subject: 1 (All 8 learners)

Syntactic frame

-surfmorph	+surfmorph
4 learners	4 learners
NP V PRT	NP V_{+prog} PRT

Intermediate representation

-surfmorph		+surfmorph	
UTAH	rUTAH	UTAH	rUTAH
Done-to as *subject*	*Highest* as *subject*	*Done-to* as *subject*	*Highest* as *subject*
2 learners	2 learners	2 learners	2 learners

Mapping to syntax

-surfmorph, UTAH		-surfmorph, rUTAH	
+expmap	*-expmap*	*+expmap*	*-expmap*
+mvmt: 1	Done-to as subject: 1	+mvmt: 0	Highest as subject: 1
1 learner	**1 learner**	**1 learner**	**1 learner**

+surfmorph, UTAH		+surfmorph, rUTAH	
+expmap	*-expmap*	*+expmap*	*-expmap*
+mvmt: 1	Done-to as subject: 1	+mvmt: 0	Highest as subject: 1
1 learner	**1 learner**	**1 learner**	**1 learner**

Today's plan

Verb classes

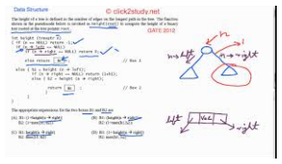
done-to

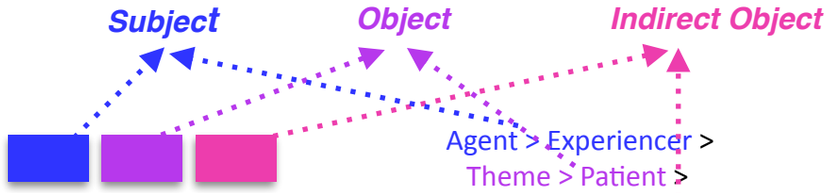
The ice melted.

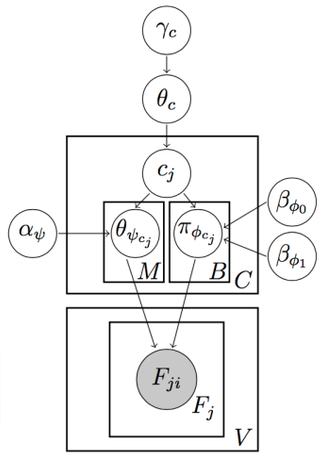
The penguin climbed.

doer

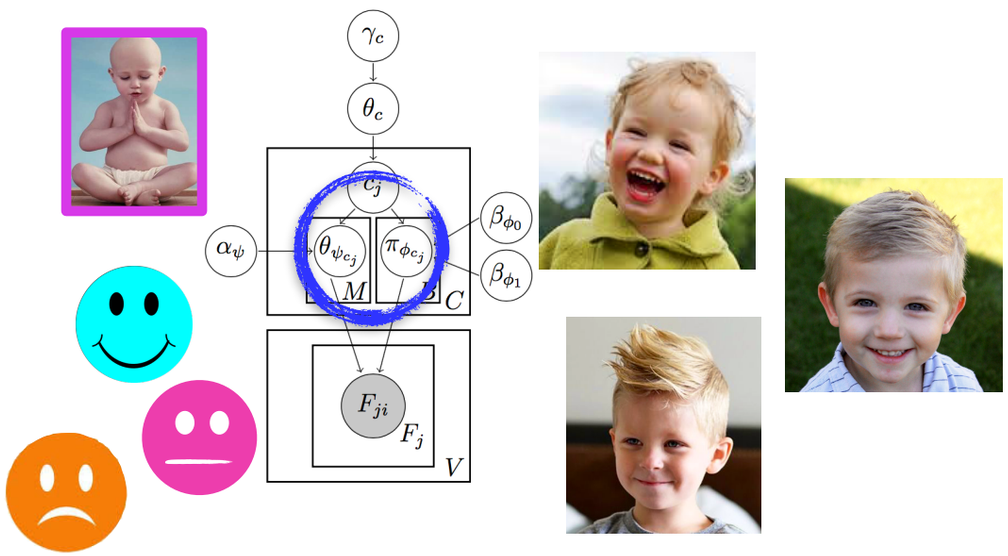
Computational modeling





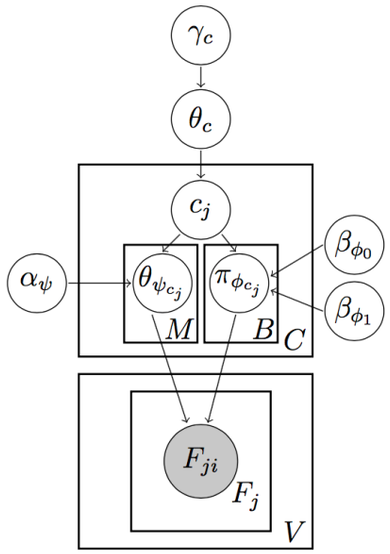


Results & implications

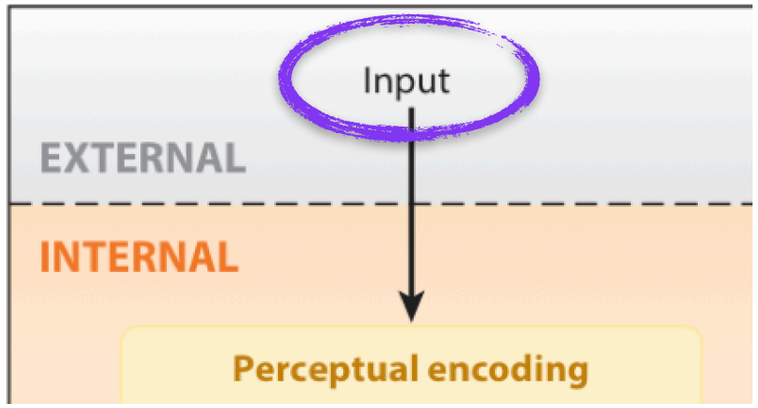


Today's plan

Computational modeling

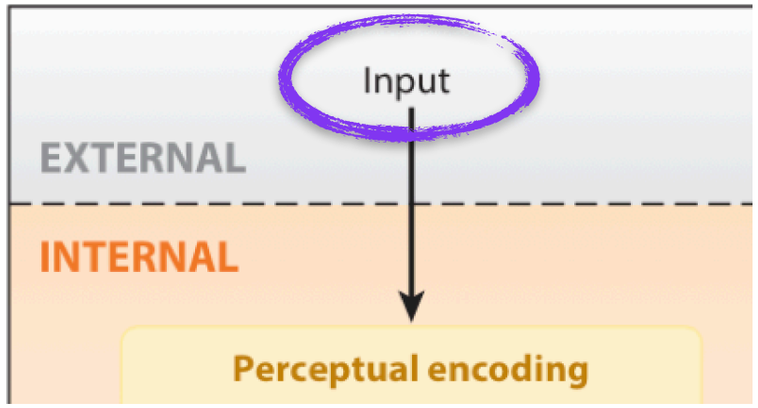


How do we model this?



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

Input



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

Input

CHILDES Treebank

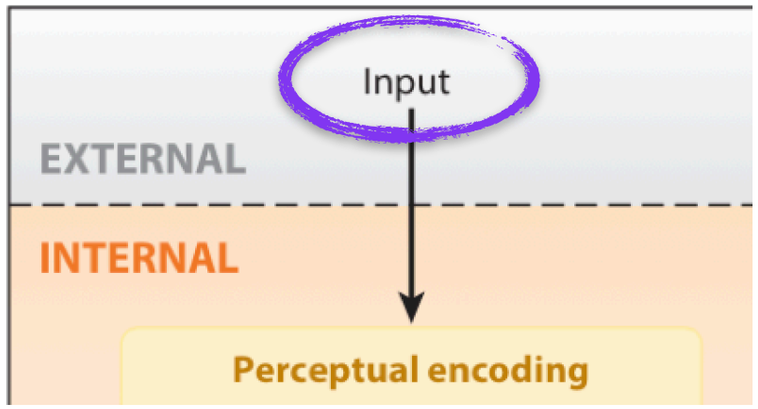
<3 years old

Brown-Eve corpus (Brown 1973) and the Valian corpus (Valian 1991), with syntactic & thematic annotations provided by the CHILDES Treebank (Pearl & Sprouse 2013).

Speech directed at 22 children between 18 and 32 months.

~40,000 utterances (~197,000 word tokens, 555 verbs)

Focus on the 239 verbs occurring 5 or more times.



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

Input

CHILDES Treebank

<3yrs

18 and 32 months
~40,000 utterances
239 verbs

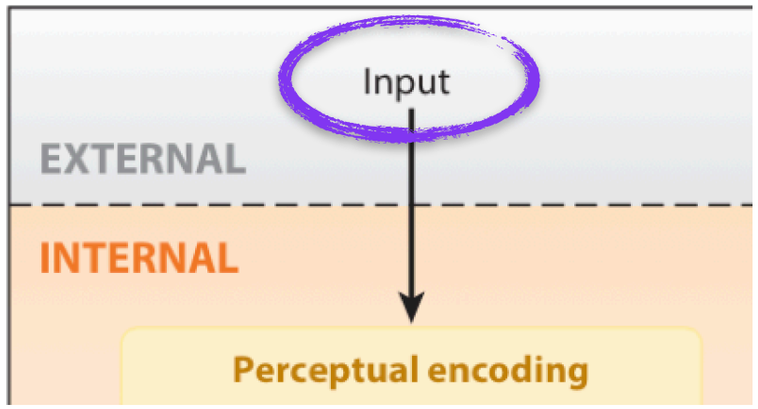
<4 years old

<3yrs + Brown-Adam subsection (Brown 1973), with syntactic & thematic annotations provided by the CHILDES Treebank (Pearl & Sprouse 2013).

Speech directed at 23 children between 18 and 48 months.

~51,000 utterances (~254,000 word tokens, 617 verbs)

Focus on the 267 verbs occurring 5 or more times.



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

Input

CHILDES Treebank

<3yrs

18 and 32 months
~40,000 utterances
239 verbs

<4yrs

18 and 48 months
~51,000 utterances
267 verbs

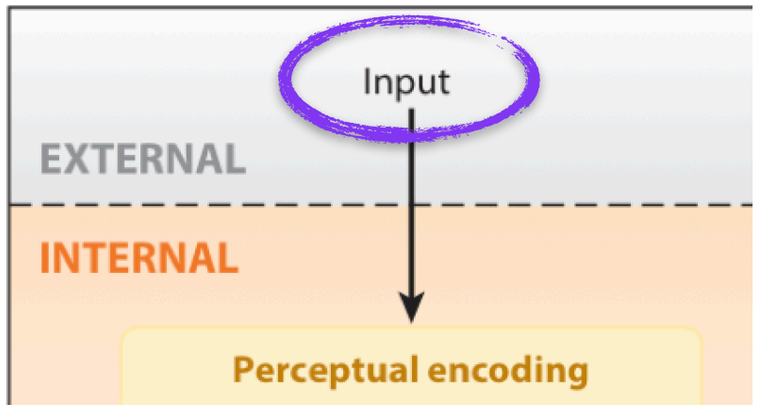
<5 years old

<4yrs + Brown-Adam subsection (Brown 1973), with syntactic & thematic annotations provided by the CHILDES Treebank (Pearl & Sprouse 2013).

Speech directed at 23 children between 18 and 58 months.

~56,500 utterances (~285,000 word tokens, 651 verbs)

Focus on the 284 verbs occurring 5 or more times.



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

Input

CHILDES Treebank

<3yrs

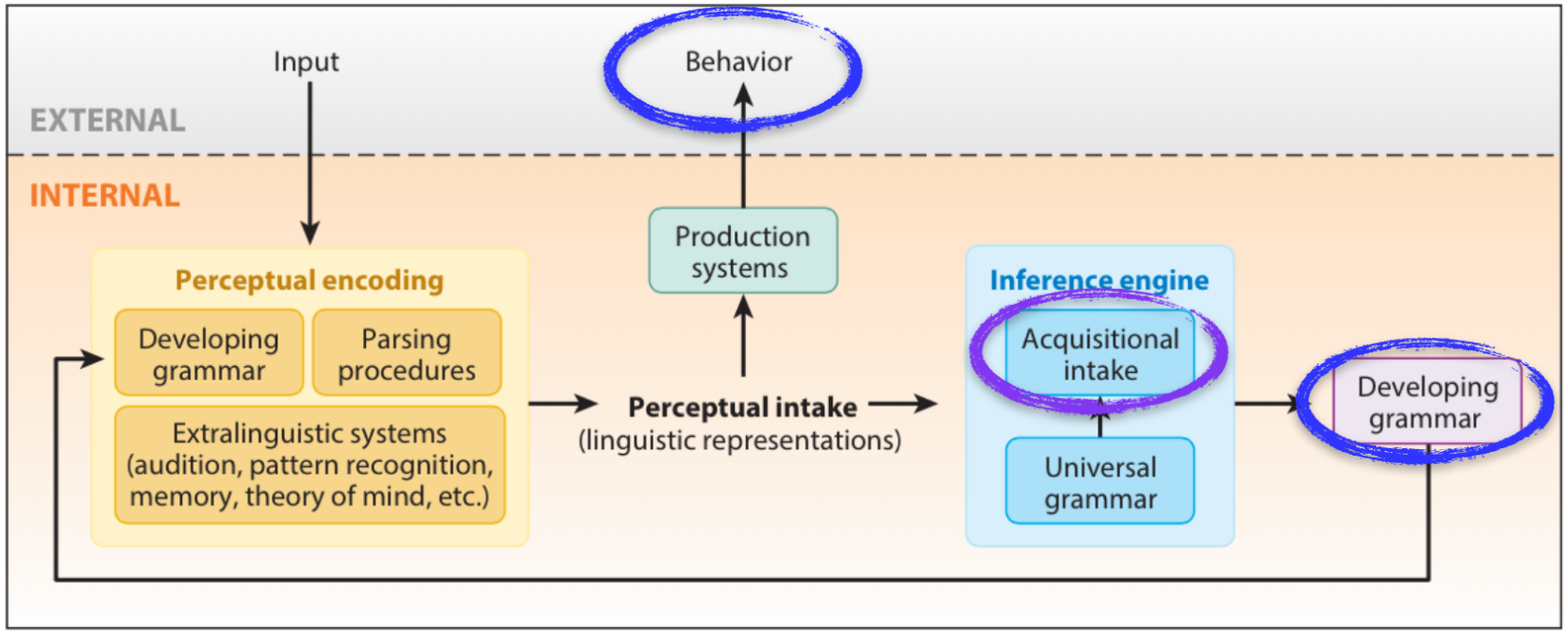
18 and 32 months
~40,000 utterances
239 verbs

<4yrs

18 and 48 months
~51,000 utterances
267 verbs

<5yrs

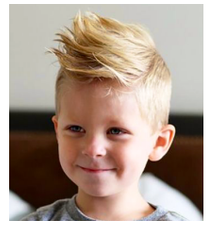
18 and 58 months
~56,500 utterances
284 verbs



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





Basic question: Is it possible for the child to use the acquisitional intake to achieve the target knowledge/ behavior?

-surfmorph
NP ___ $S_{nonfinite}$

+animate

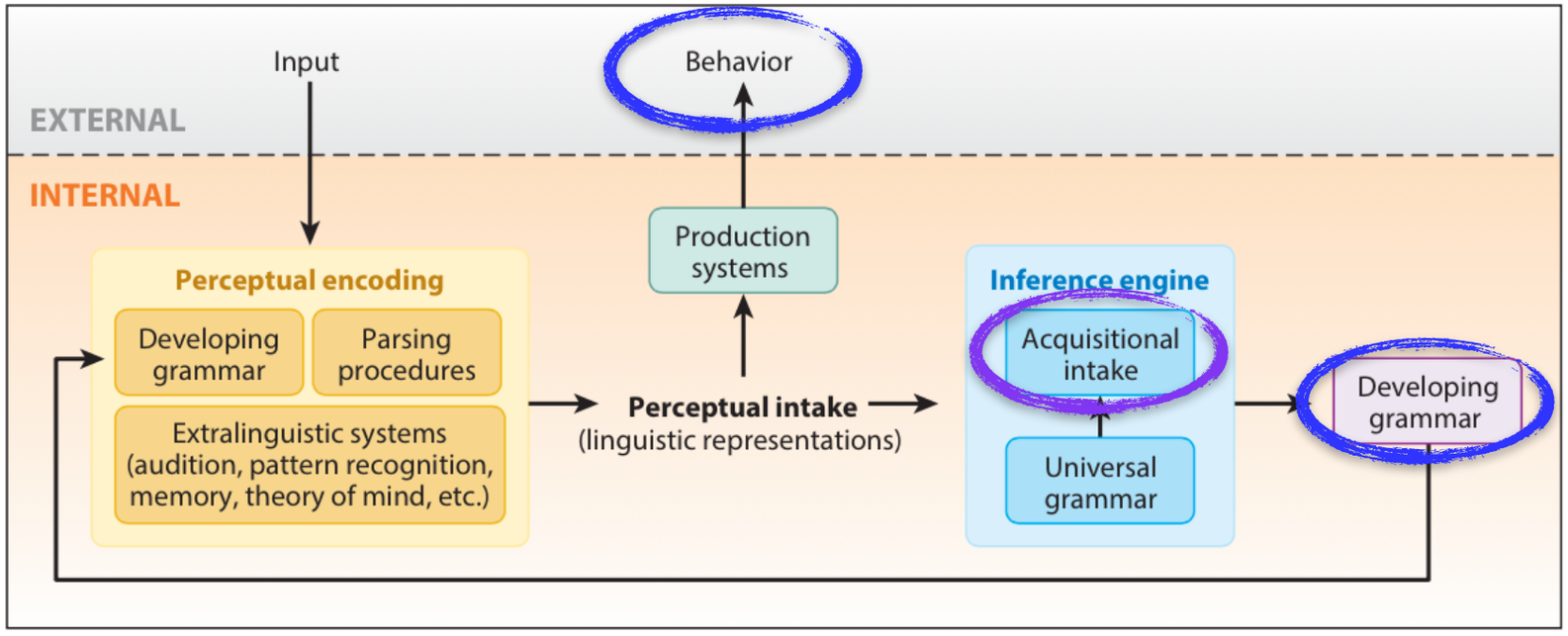
+surfmorph
NP ___**+past** $S_{nonfinite}$

UTAH

rUTAH **Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)**

-expmap ***Subject*** ***Object*** ***Indirect Object***

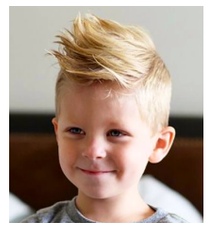
+expmap *movement?*



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**

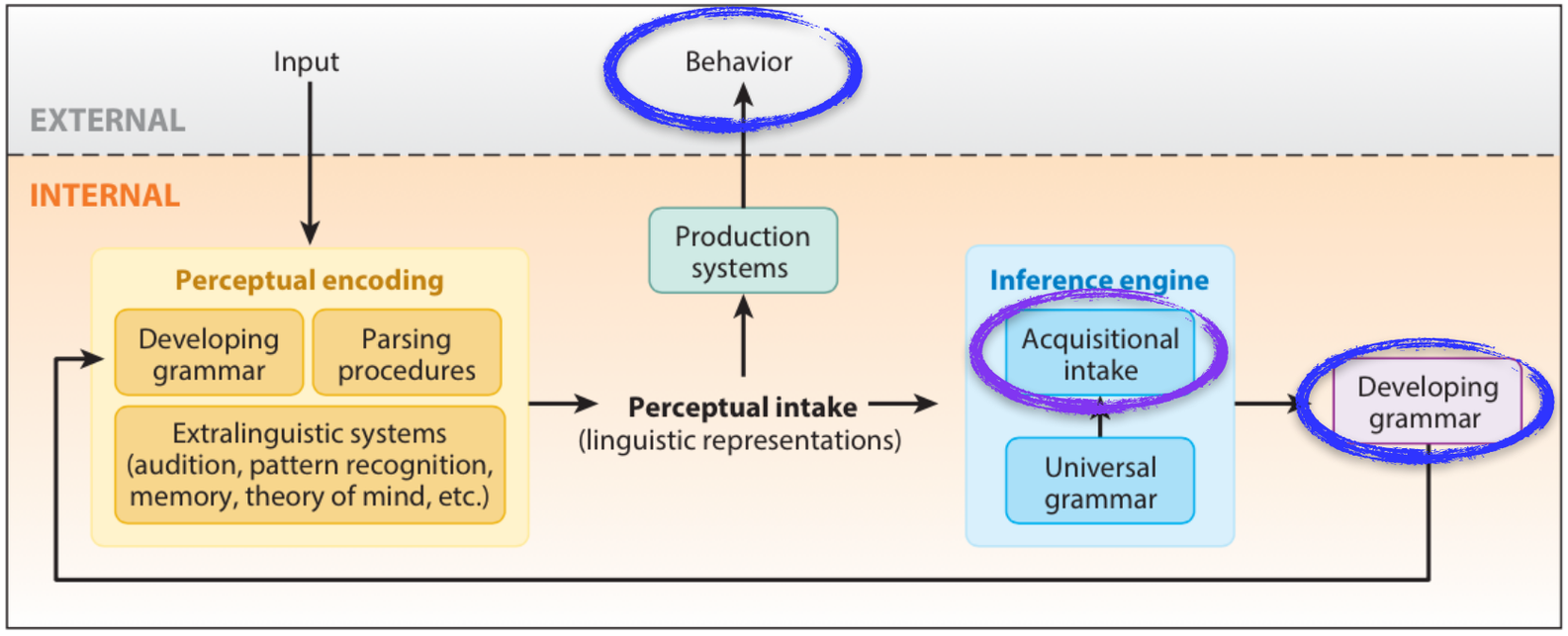




Basic question: Is it possible for the child to use the acquisitional intake to achieve the target knowledge/behavior?

This is the goal of learnability approaches (computational-level of analysis: Marr 1982)

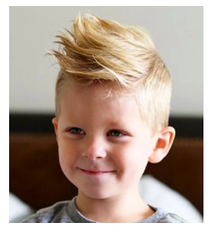
Frank et al. 2009, Goldwater et al. 2009, Pearl et al. 2010, Pearl 2011, Legate & Yang 2012, Dillon et al. 2013, Doyle & Levy 2013, Feldman et al. 2013, Orita et al. 2013



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





Basic question: Is it possible for the child to use the acquisitional intake to achieve the target knowledge/behavior?

Ideal learner model: not concerned with the cognitive limitations and incremental learning restrictions children have.

Concerned with what assumptions are useful for children to have.

-surfmorph

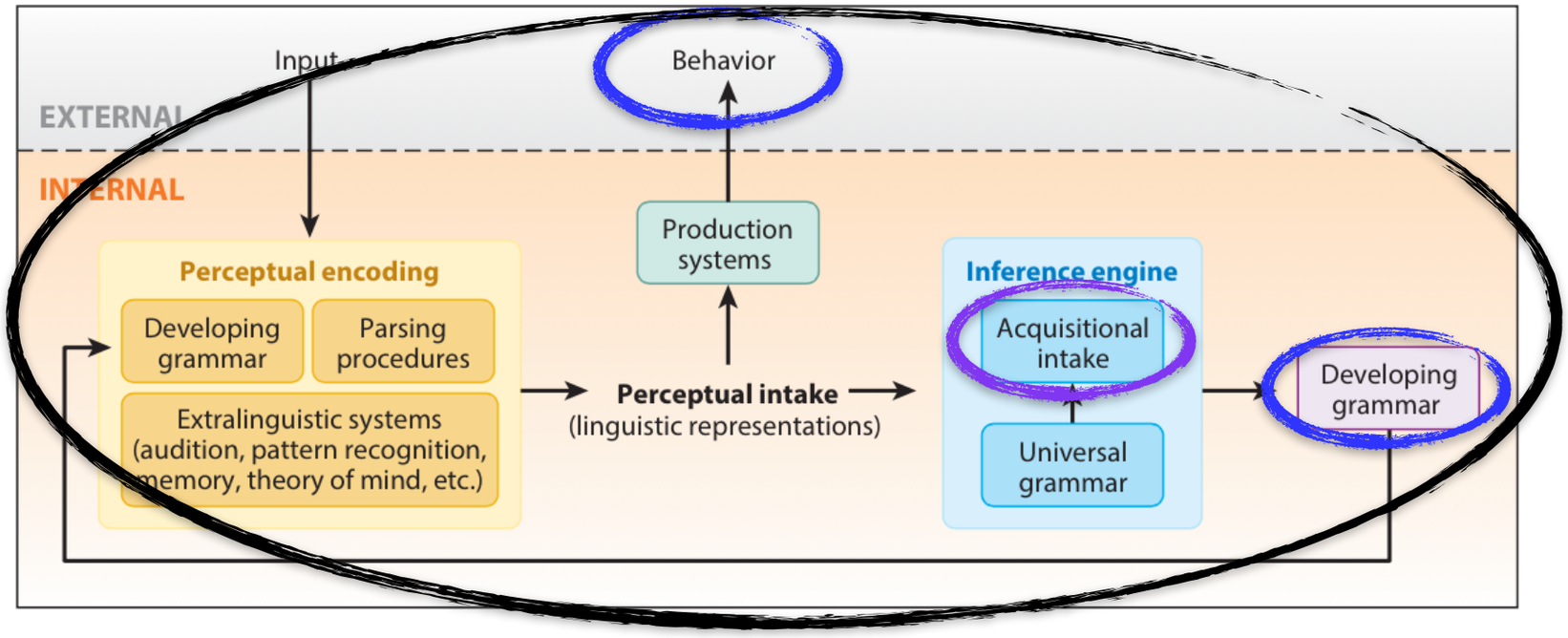
+surfmorph

UTAH

rUTAH

-expmap

+expmap



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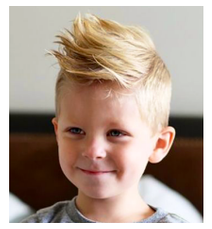
<3yrs **<4yrs** **<5yrs**





Basic question: Is it possible for the child to use the acquisitional intake to achieve the target knowledge/behavior?

Ideal learner model: Also an excellent first step to see if this is the **right conceptualization** of the acquisition task.

-surfmorph

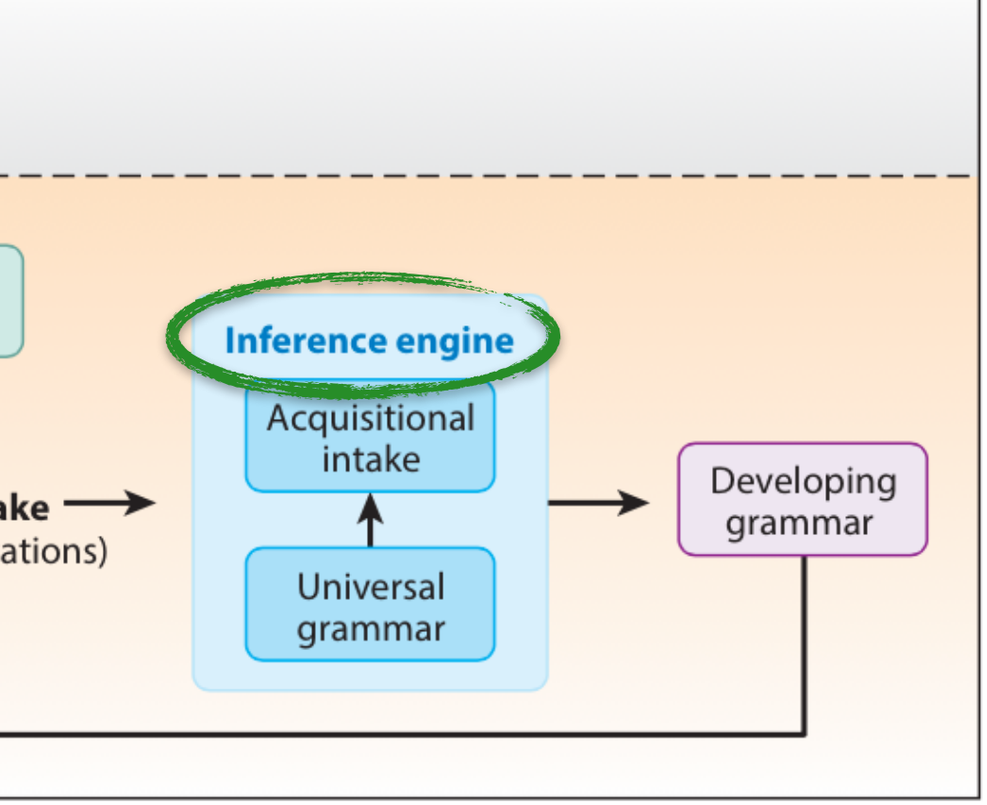
+surfmorph

UTAH

rUTAH

-expmap

+expmap

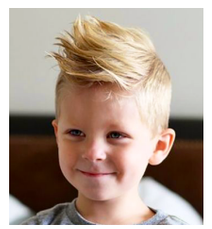


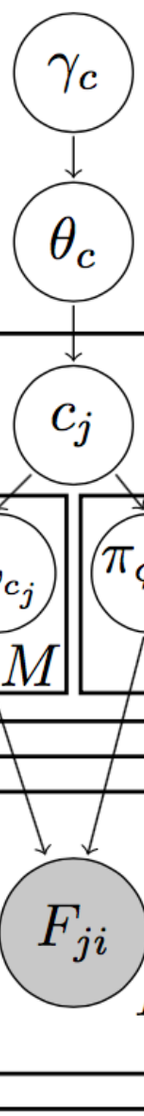
Learners use a generative model of how the observable data for each verb are created.

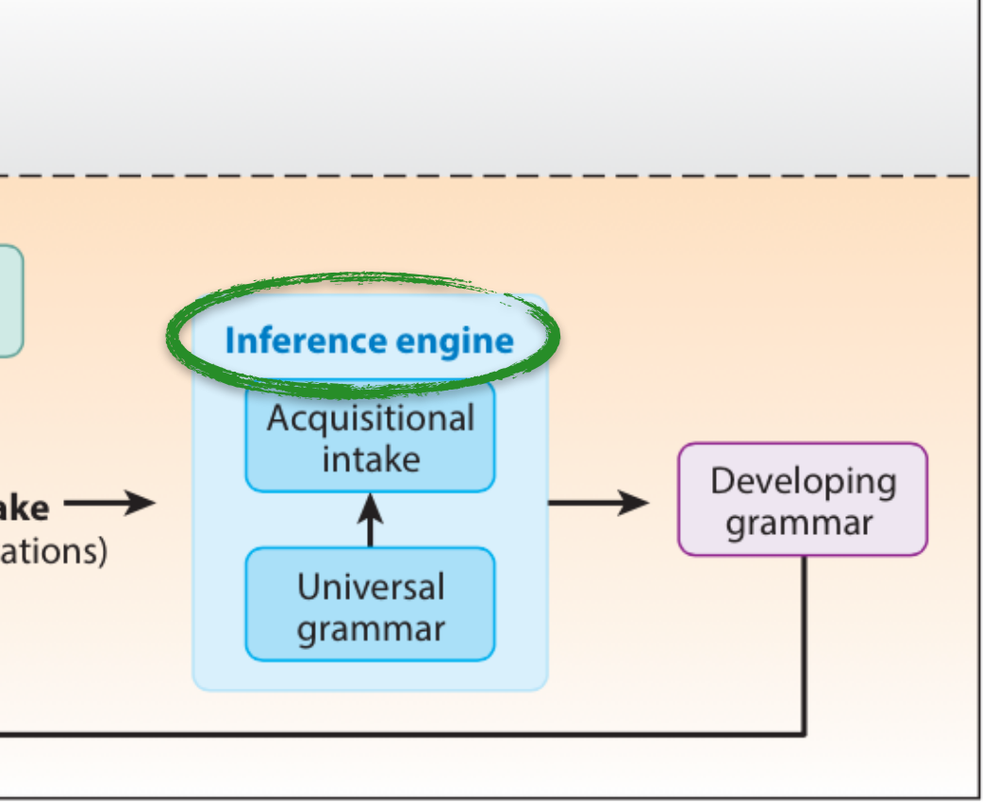
Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**









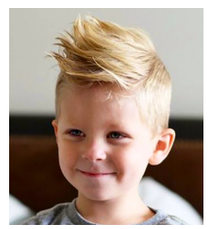
Learners use a generative model of how the observable data for each verb are created.

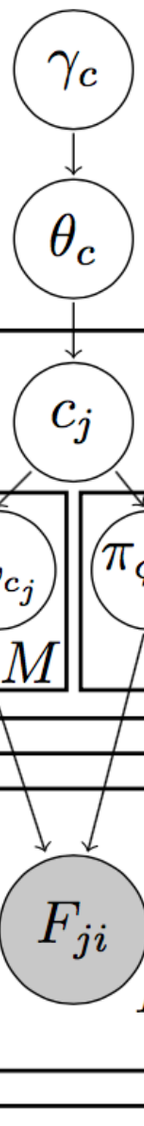
FALL

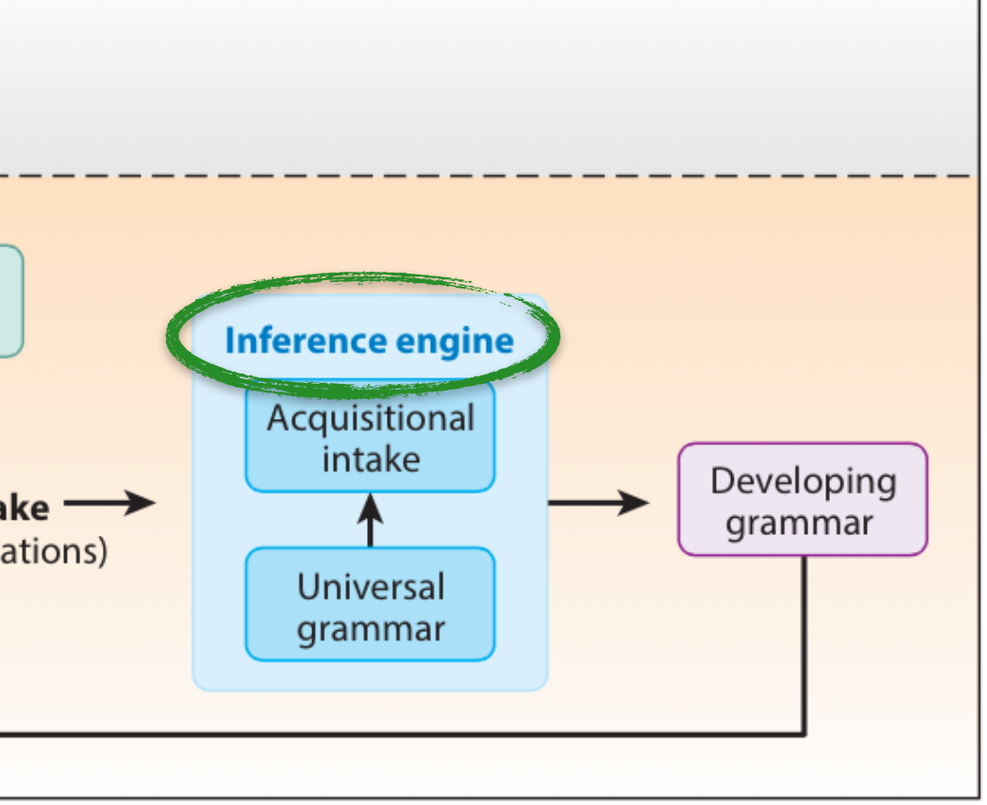
Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





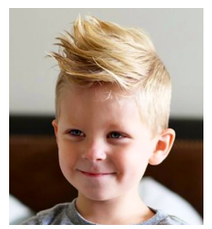




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





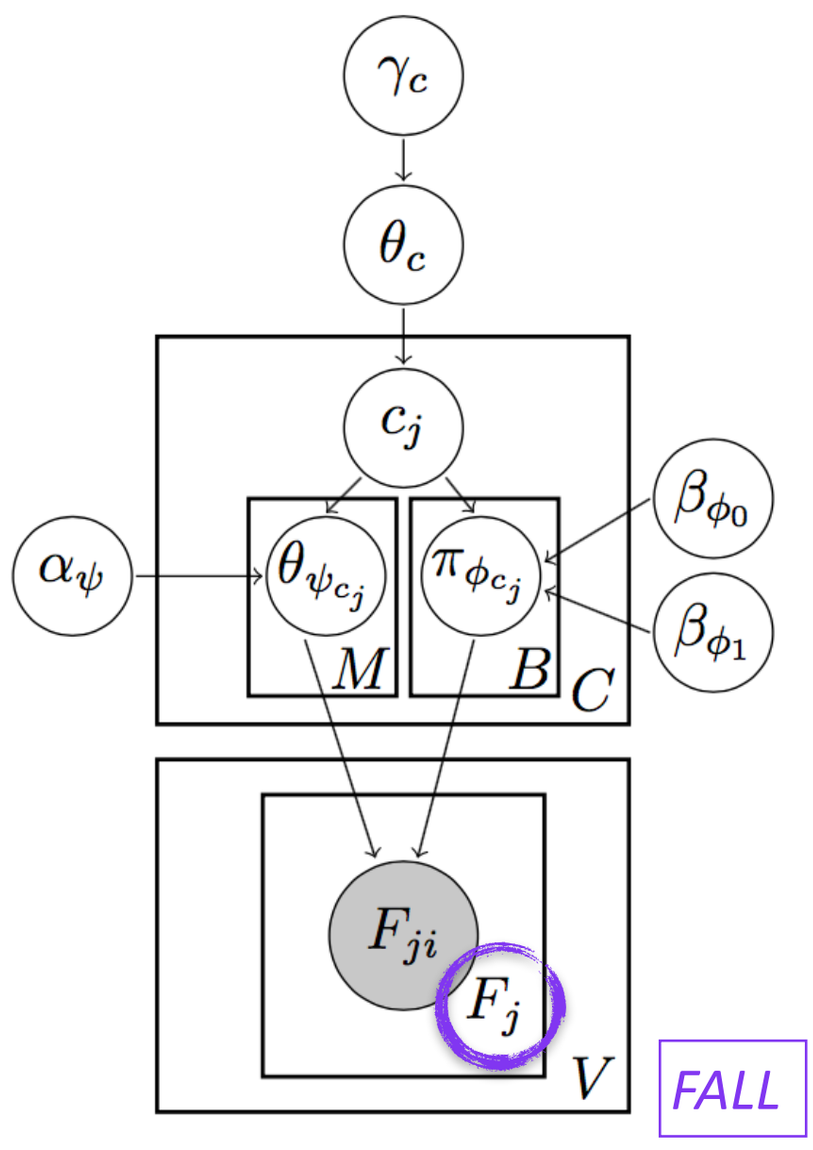
Each verb appears in a certain number of instances in the input.

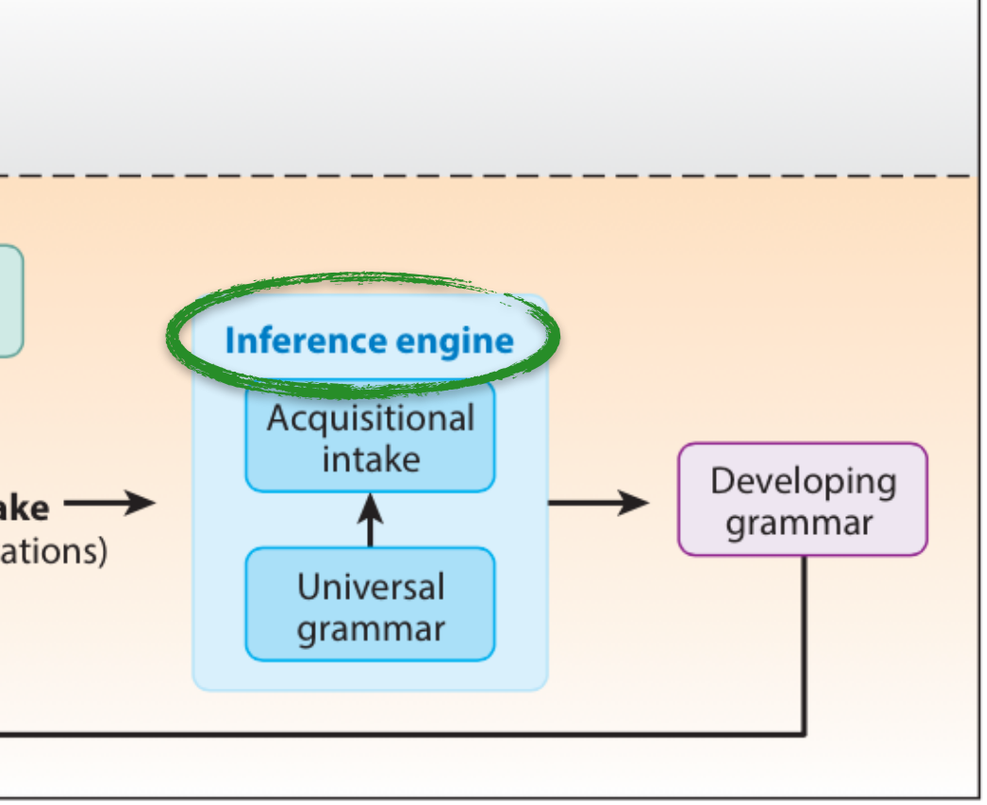
"it's falling off"

"she fell down"

"don't fall!"

"is London Bridge falling down?"

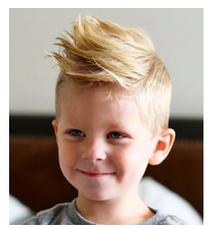




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

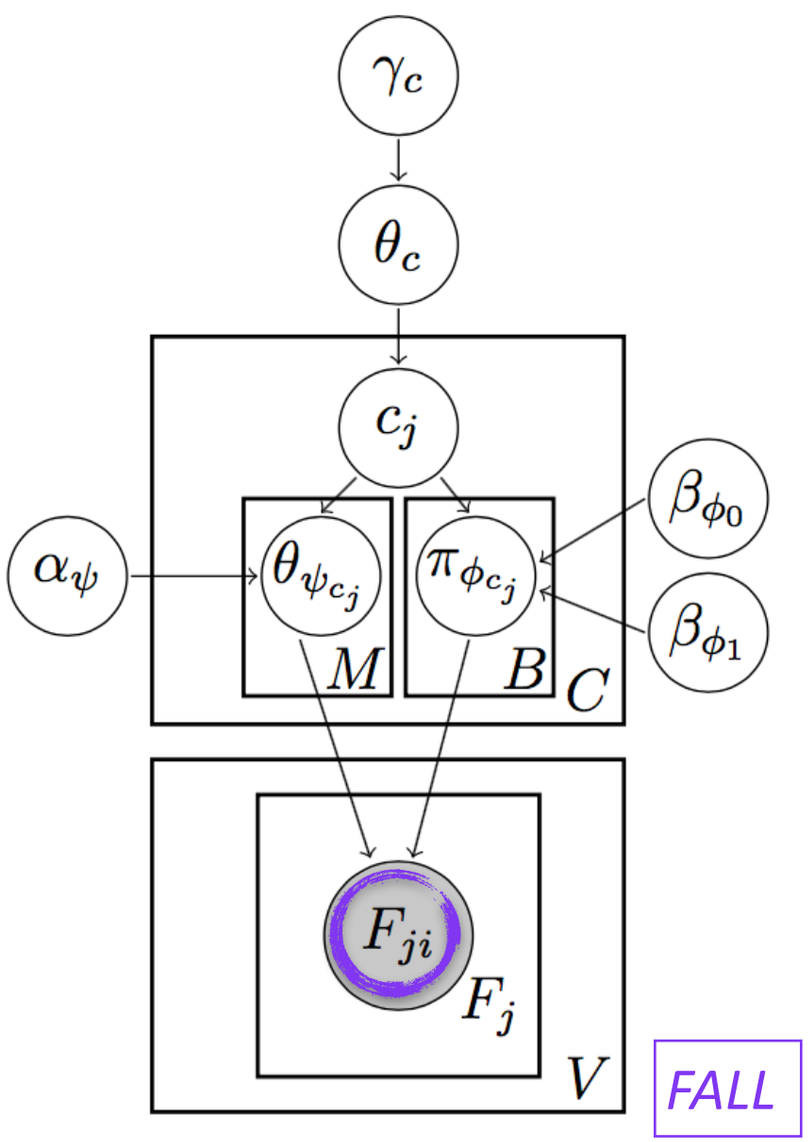
<3yrs **<4yrs** **<5yrs**

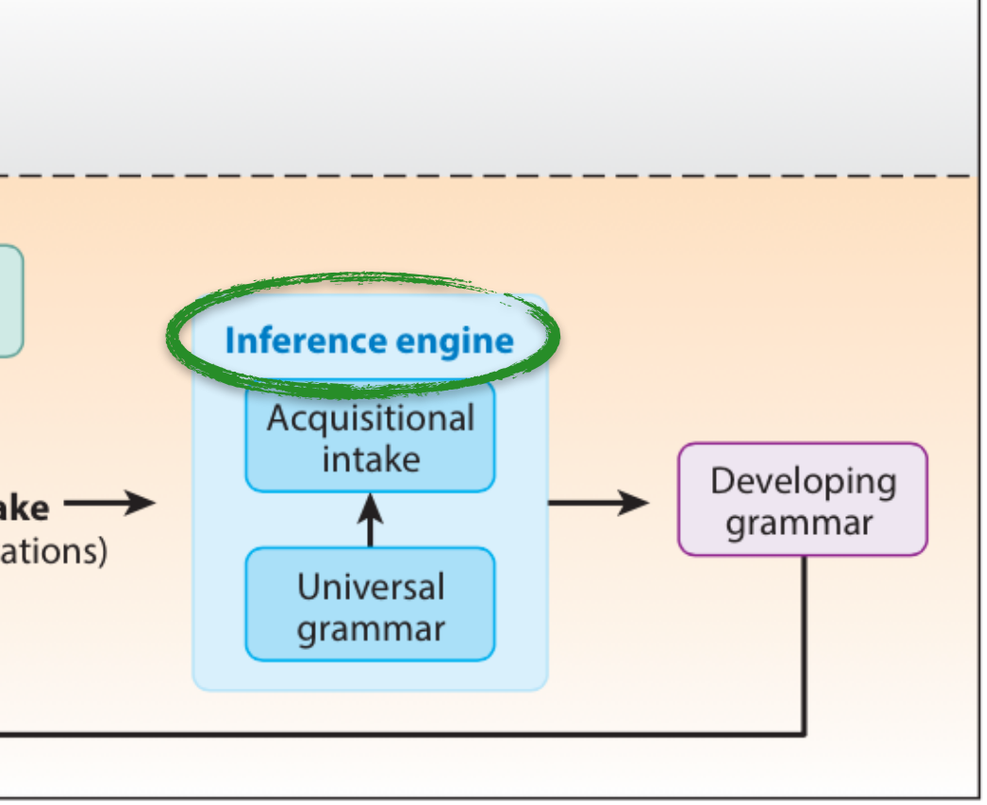




Each instance is observed some number of times.

(3x) “it’s falling off”
“it’s falling off”
“it’s falling off”





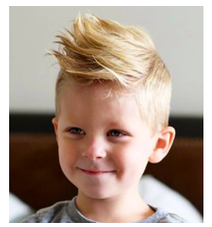
Each verb belongs to some class which determines its linguistic behavior.

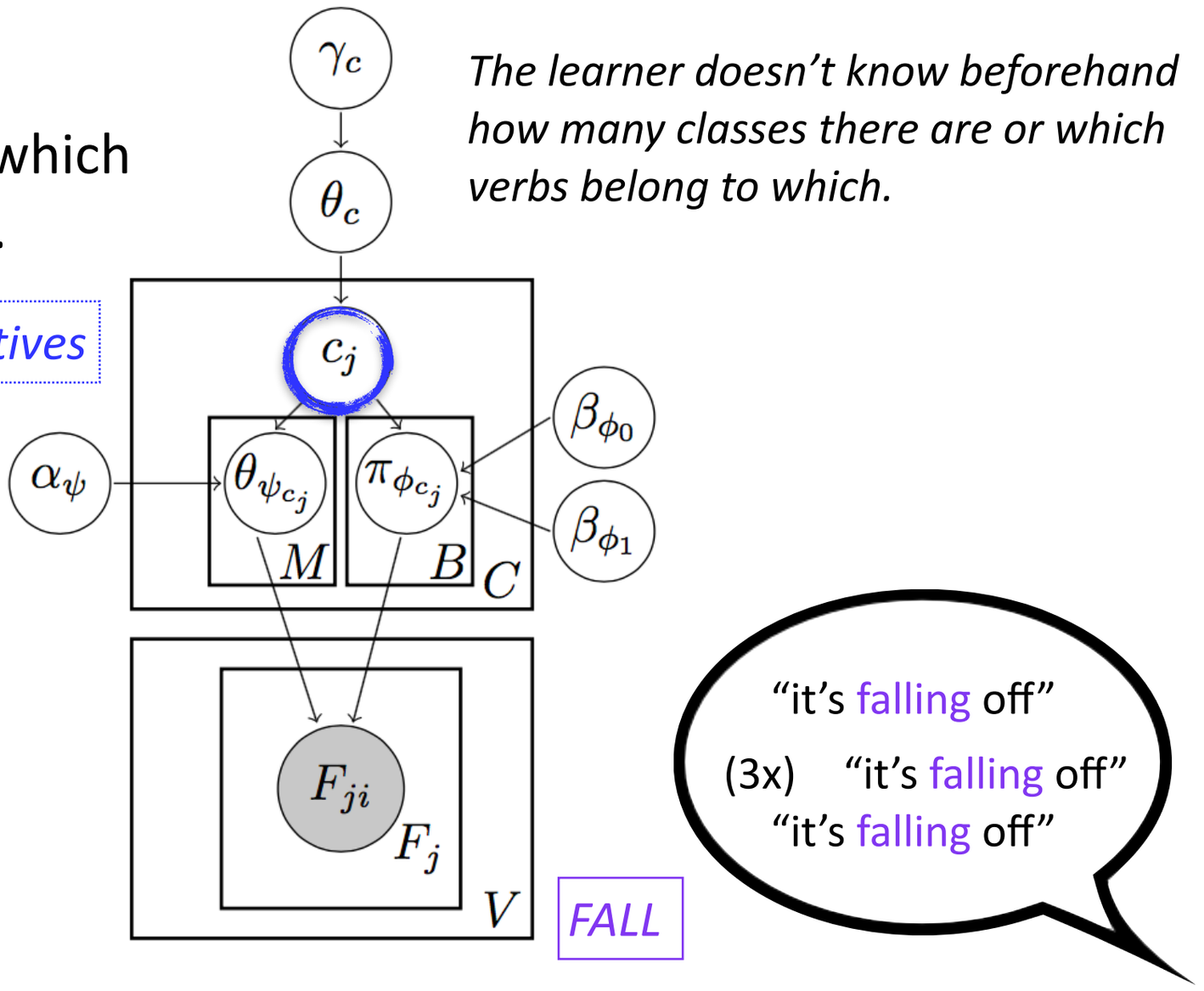
Objective: Infer verb class

Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**

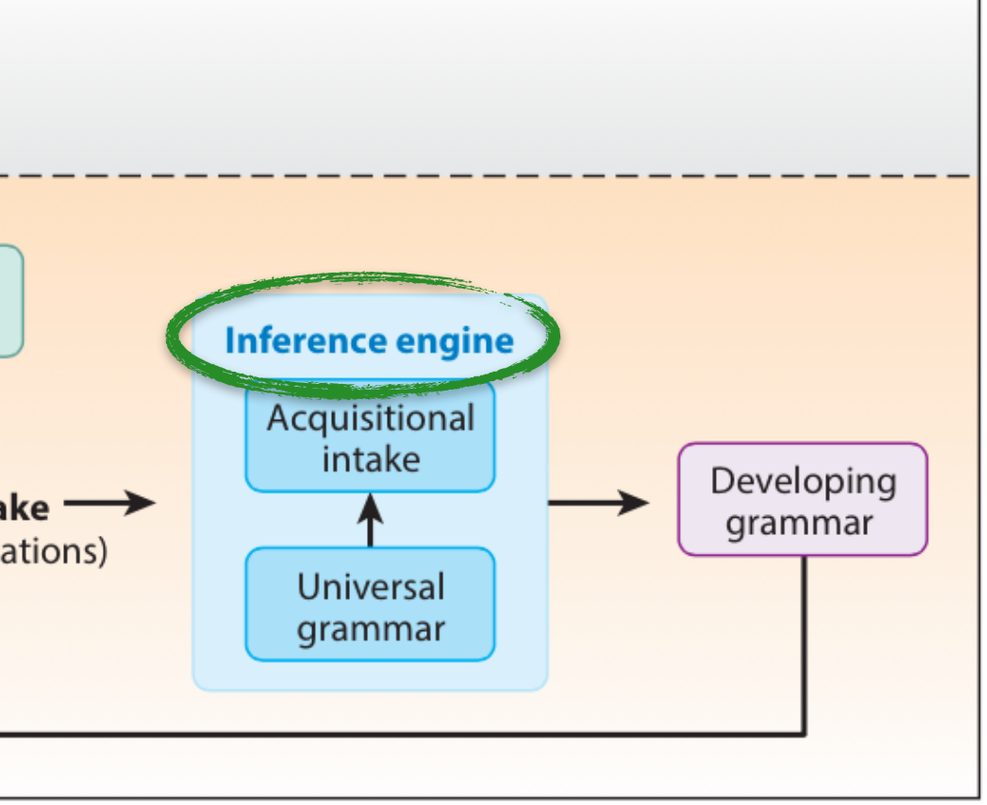






unaccusatives

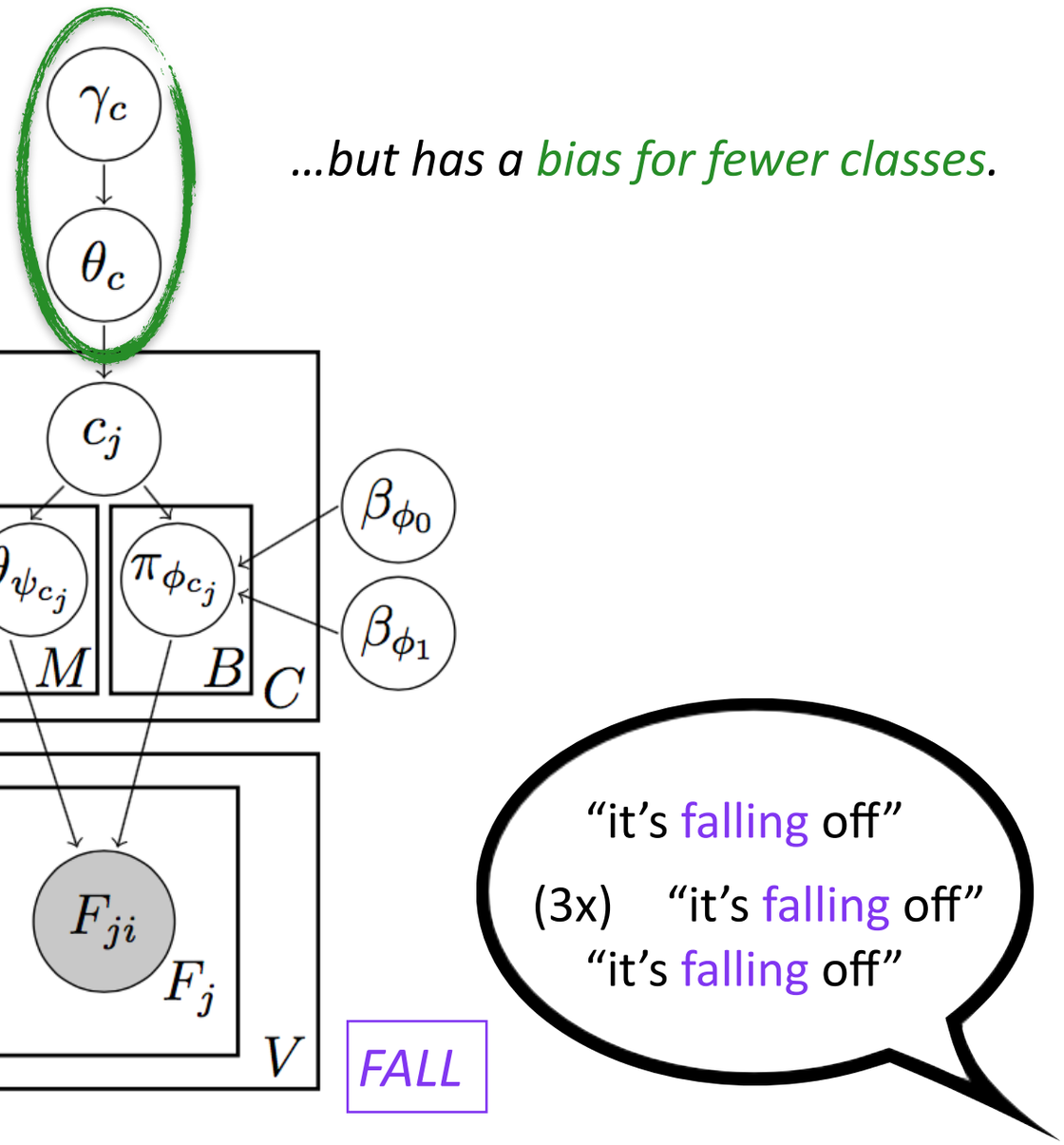
The learner doesn't know beforehand how many classes there are or which verbs belong to which.



Each verb belongs to some class which determines its linguistic behavior.

unaccusatives

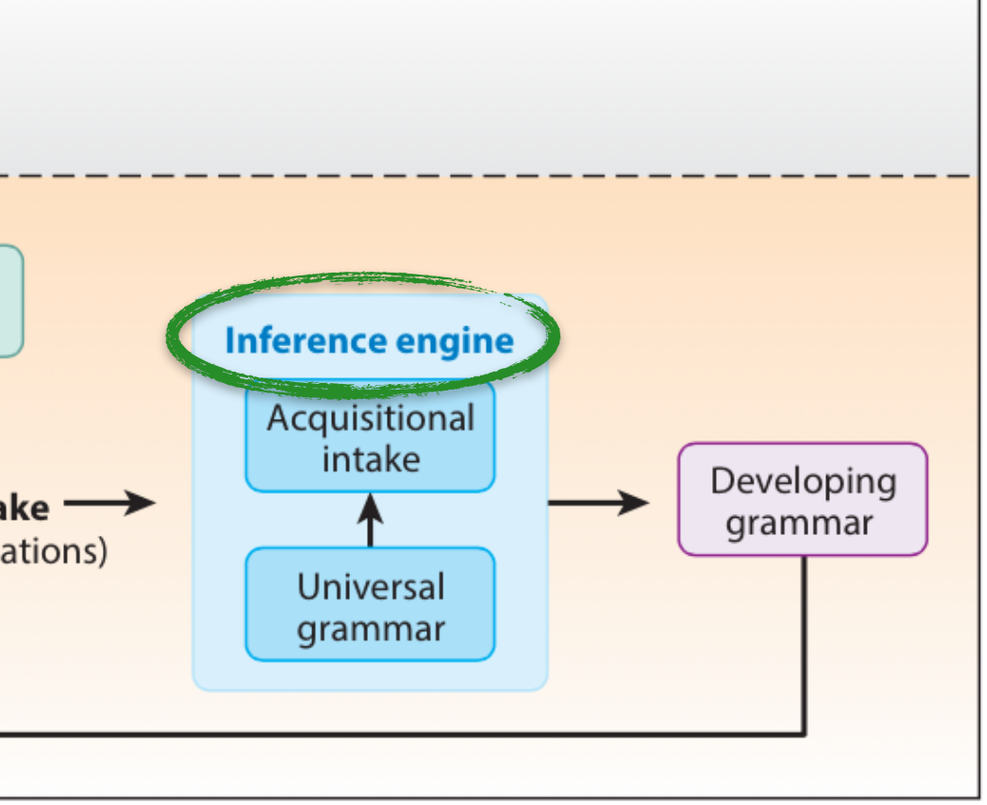
Objective: Infer verb class



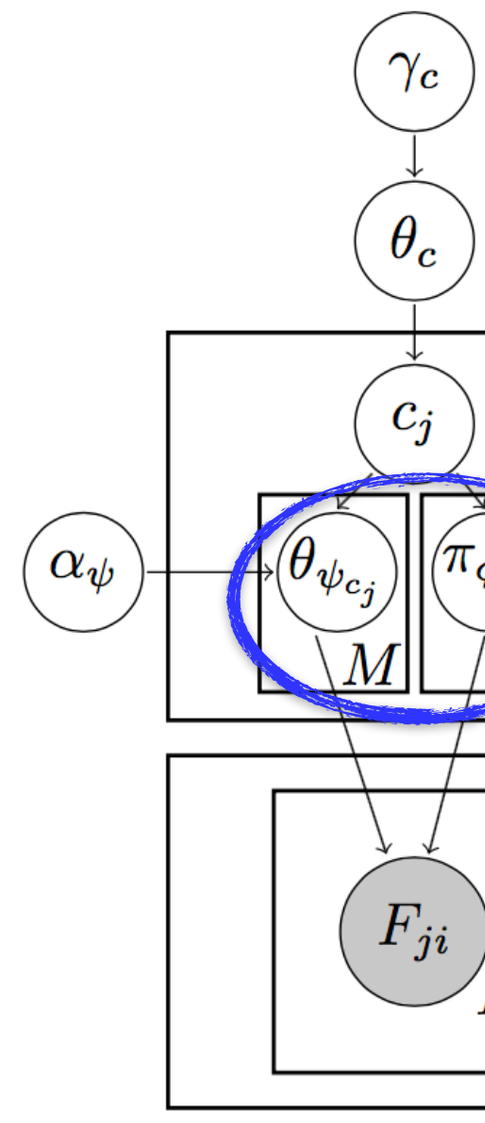
Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**

…but has a bias for fewer classes.



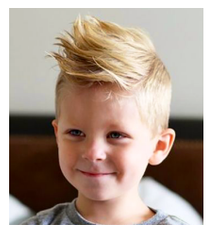
Depending on the verb class, the observed usage will have certain characteristics.



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**

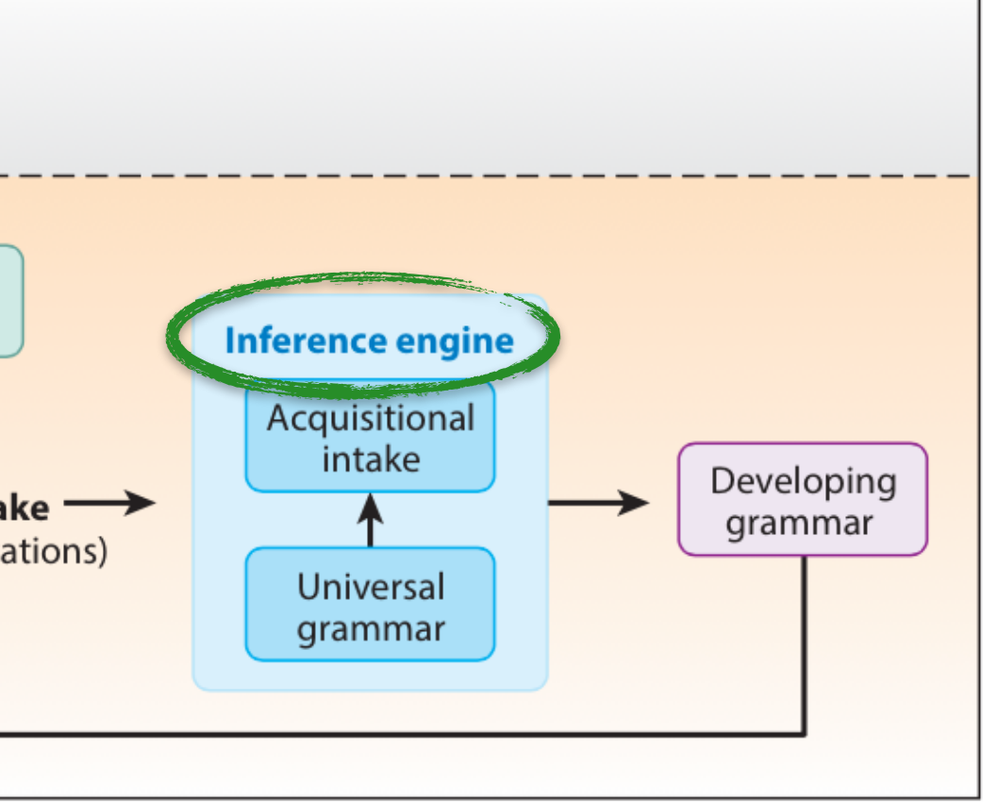




unaccusatives

FALL

"it's falling off"
(3x) "it's falling off"
"it's falling off"

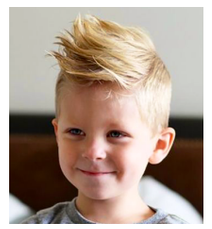


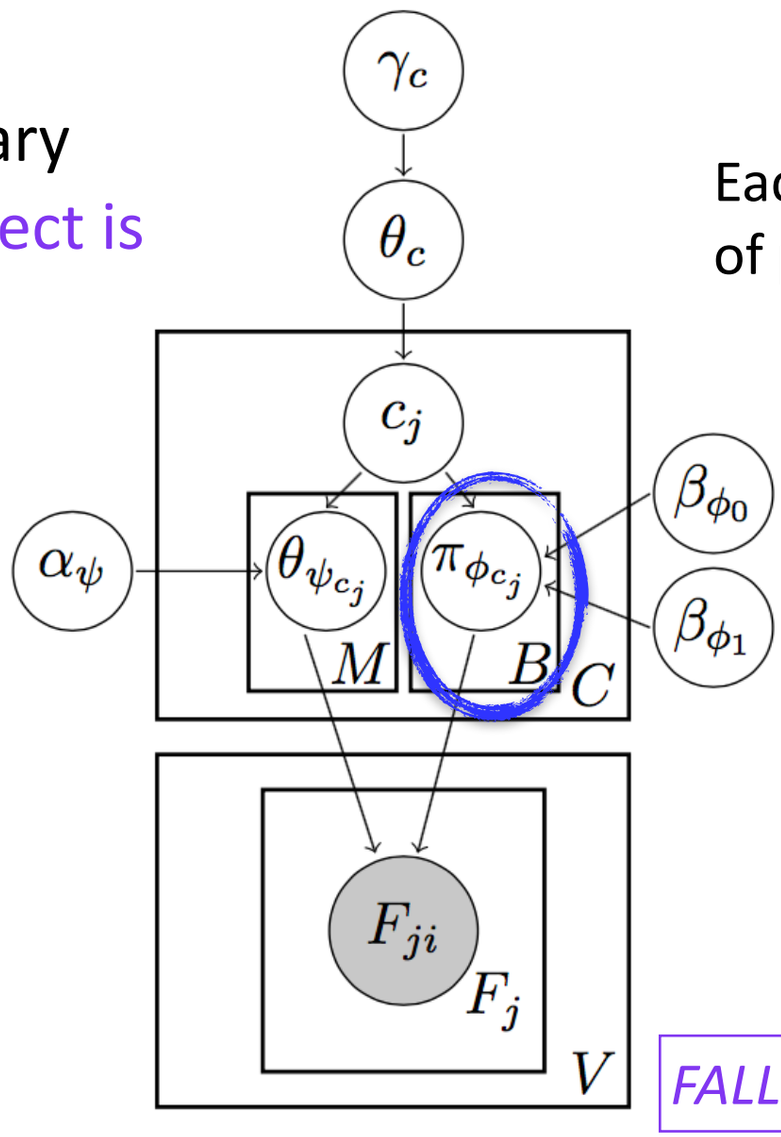
These characteristics include binary choices such as whether the subject is animate or not.

Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**







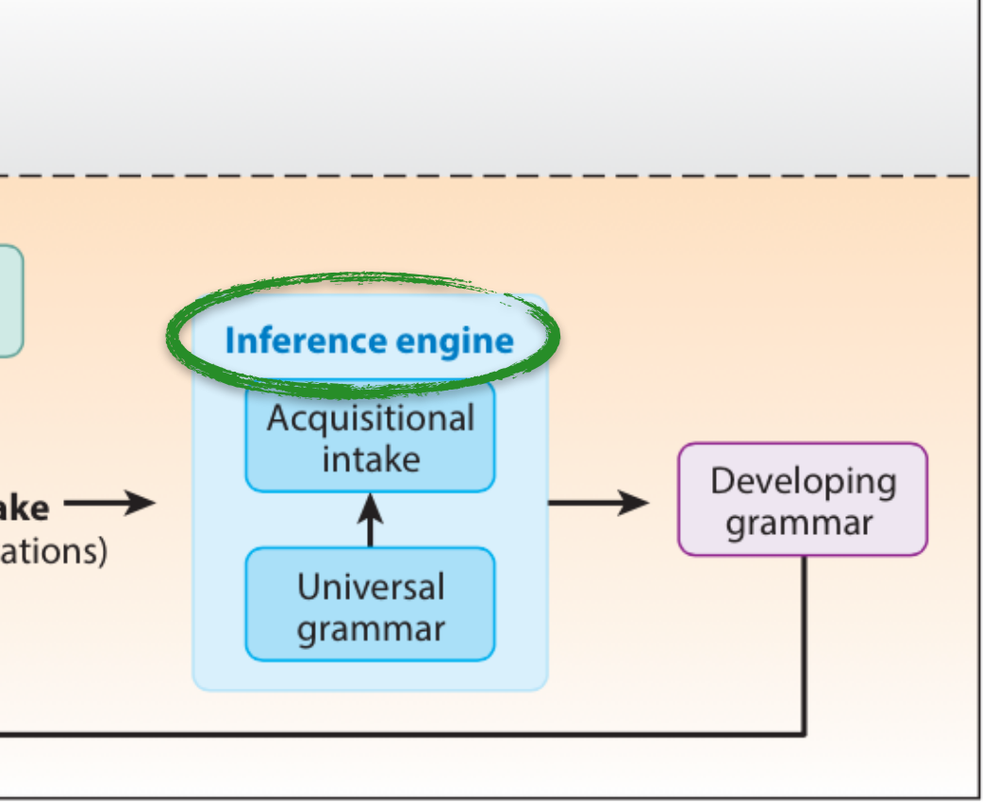
Each class has a probability of preferring each option.

unaccusatives

+anim	*Subject*	*-anim*
0.3		***0.7***

-anim
"**it**'s falling off"
(3x) "it's falling off"
"it's falling off"

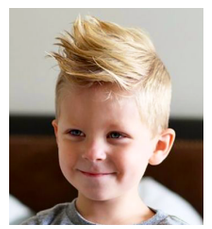
FALL



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





Binary choices:

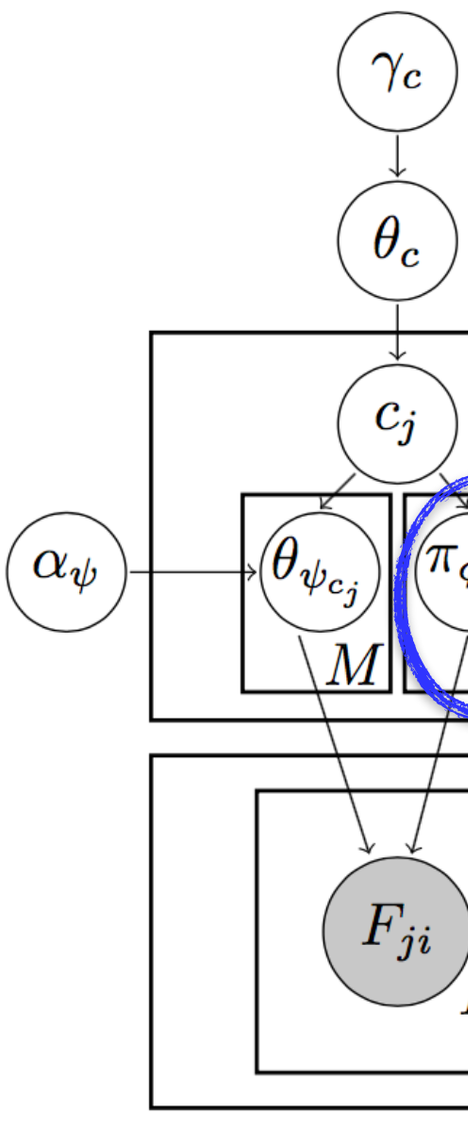
+/-animate subject
+/-animate object
+/-animate indirect object
+/-movement (when +exp-mapping)

+animate

-animate

Subject ***Object*** ***Indirect Object***

movement?



unaccusatives

+anim ***Subject*** ***-anim***

0.3 ***0.7***

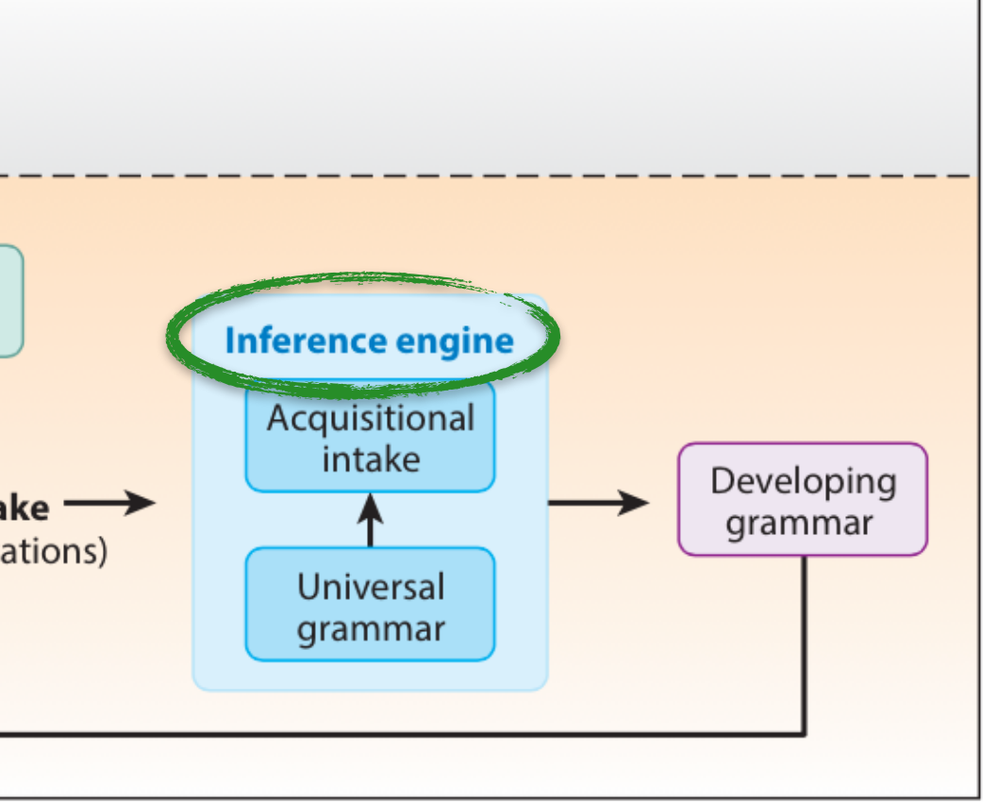
FALL

-anim

"**it**'s falling off"

(3x) "it's falling off"

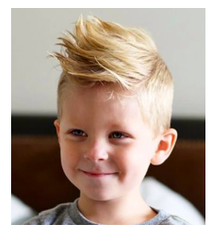
"it's falling off"

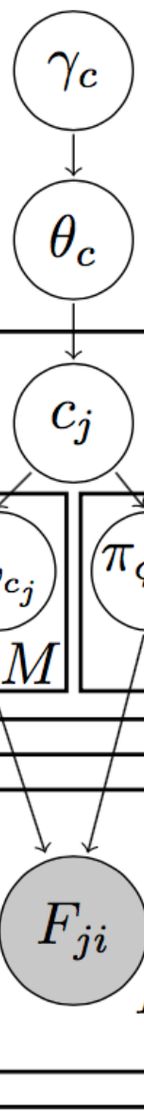


Goal: Model the
developmental trajectory
from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**







The learner infers these probabilities, and begins with no bias towards either option per class.

Binary choices:

+animate

-animate

Subject ***Object*** ***Indirect Object***

movement?

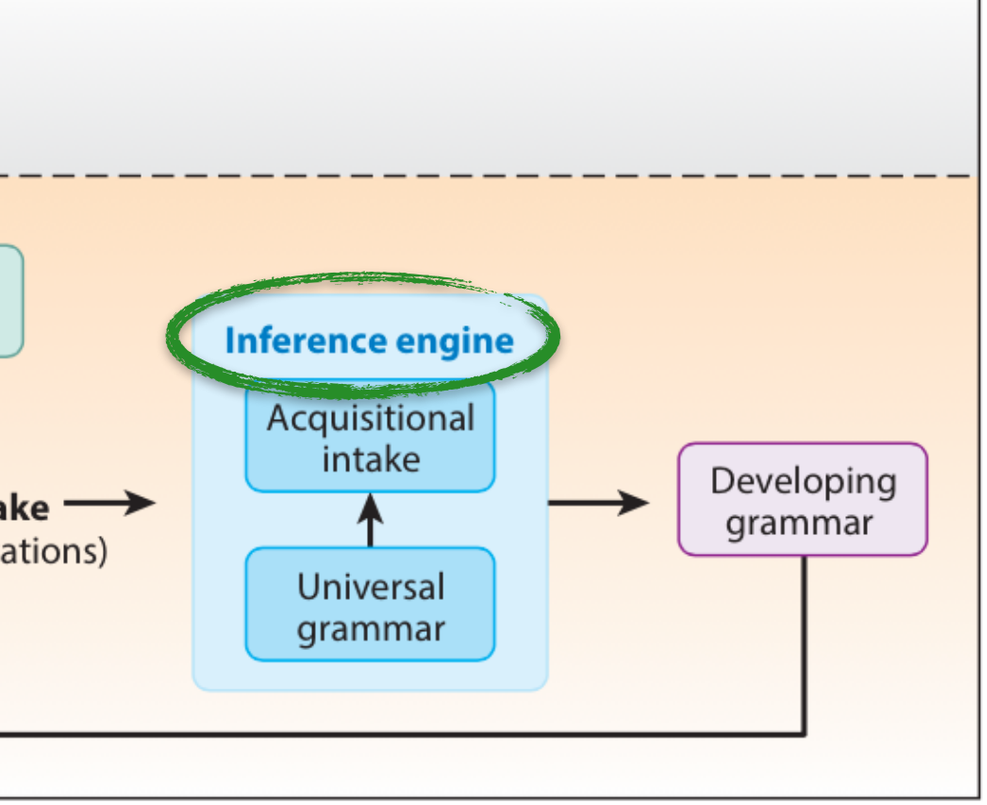
unaccusatives

+anim ***Subject*** ***-anim***

0.3 ***0.7***

-anim
"**it**'s falling off"
(3x) "it's falling off"
"it's falling off"

FALL



These characteristics include multinomial choices such as which syntactic frame a verb appears in.

Each class has a probability of preferring each option.

NP V PRT ***0.3***

NP V ***0.25***

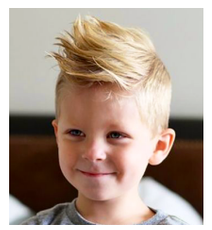
…

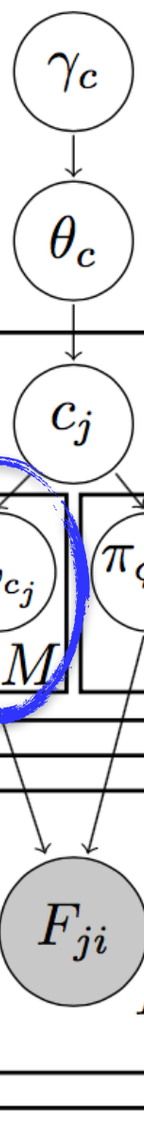
NP V S ***0***

Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**







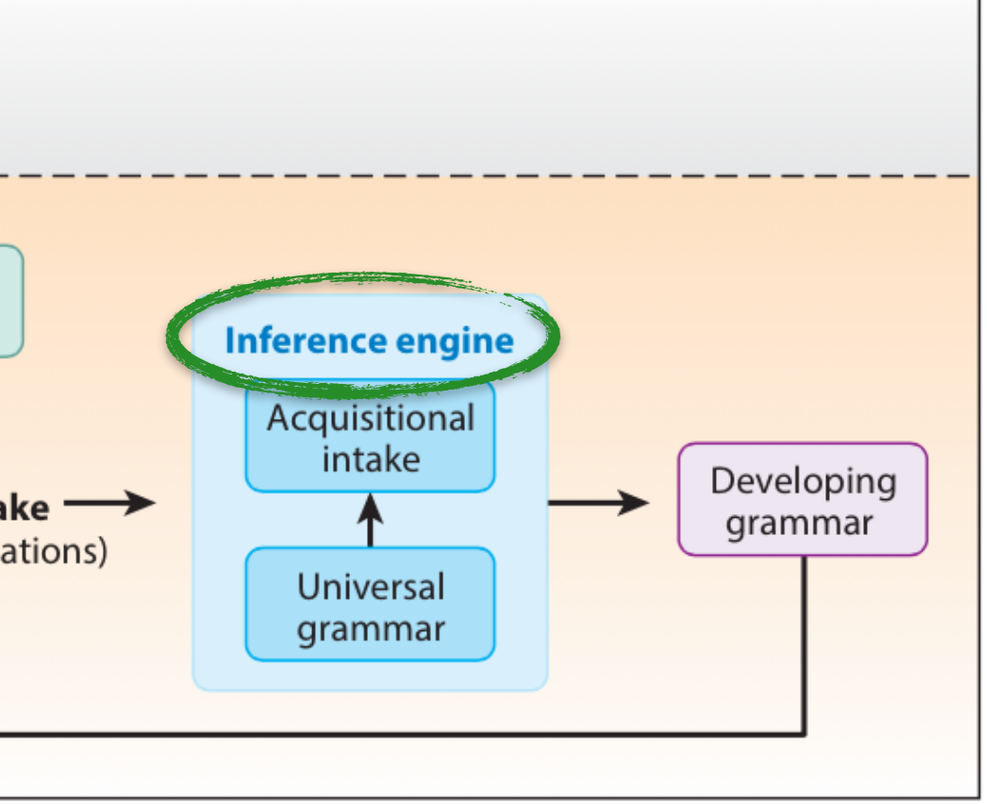
unaccusatives

+anim ***Subject*** ***-anim***

0.3 ***0.7***

FALL

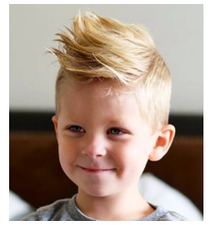
-anim
“it’s falling off”
(3x) ***NP V*** ***PRT***
“it’s falling off”
“it’s falling off”



Goal: Model the
developmental trajectory
from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



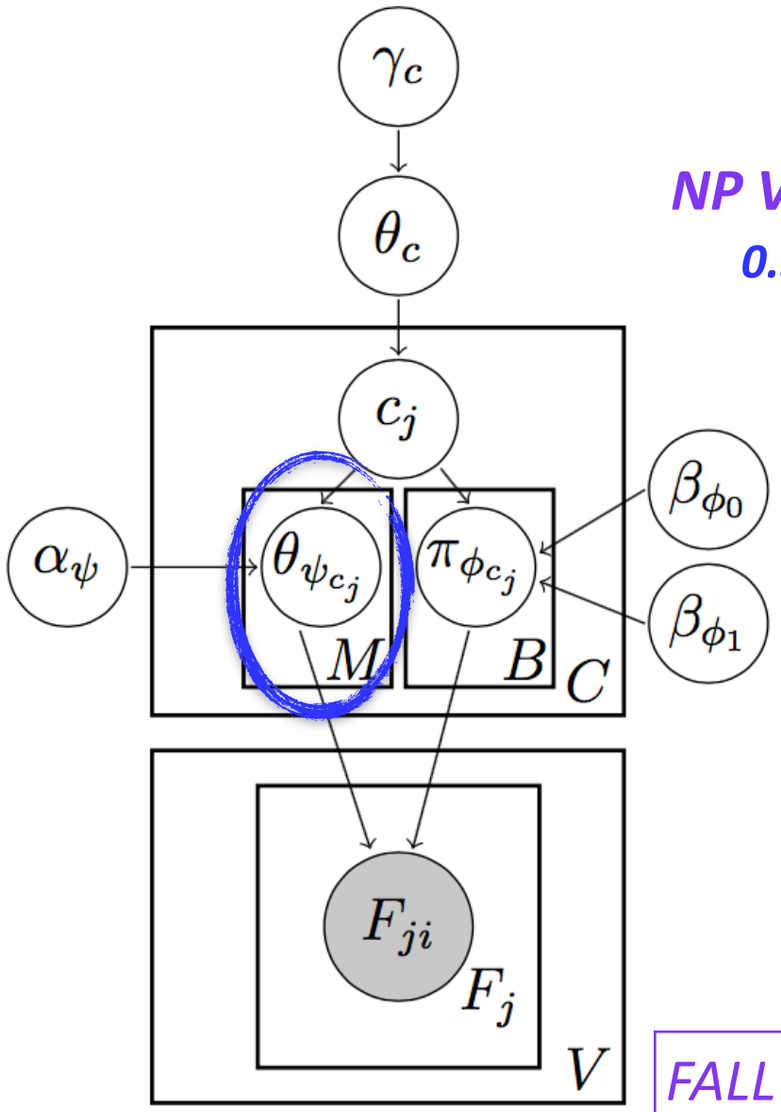


Multinomial choices:

which syntactic frame is used ***NP V PRT***
(if -exp-mapping)
- position of doer/Highest role
- position of done-to/next-highest role
- position of done-by/third-highest role

Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)

Subject ***Object*** ***Indirect Object***



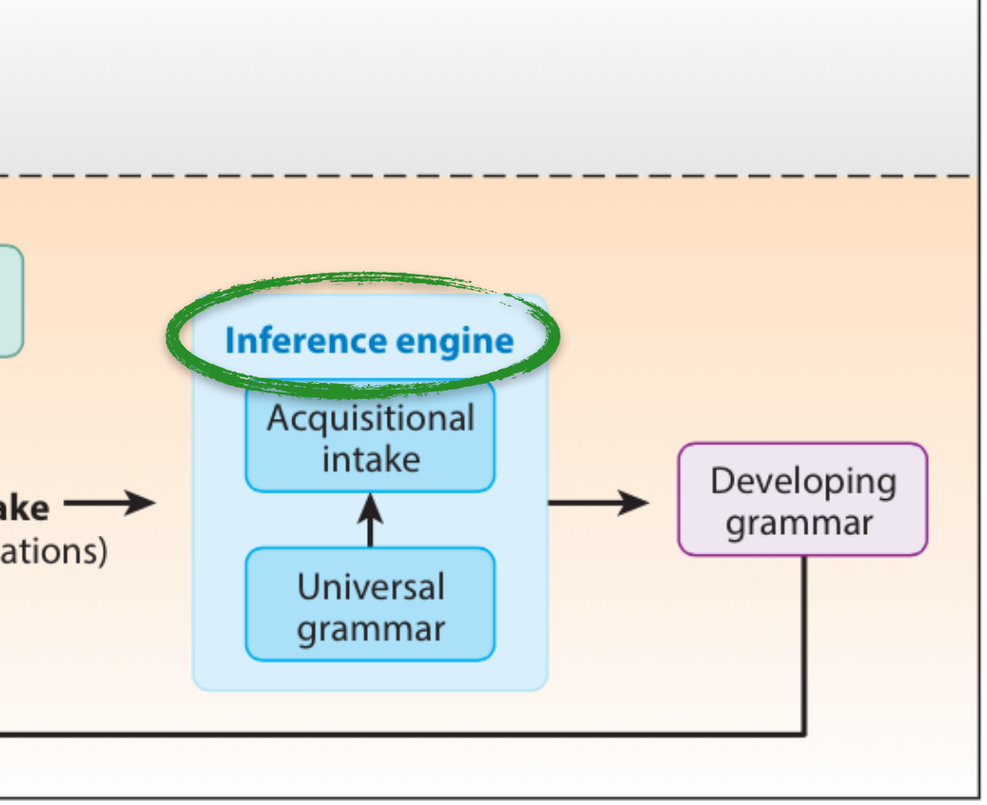
NP V ***…***
NP V PRT ***0.25*** ***NP V S***
0.3 ***0***

unaccusatives

+anim ***Subject*** ***-anim***
0.3 ***0.7***

FALL

-anim
"it's falling off"
(3x) ***NP V*** ***PRT***
"it's falling off"
"it's falling off"

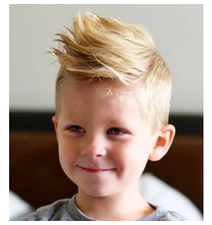


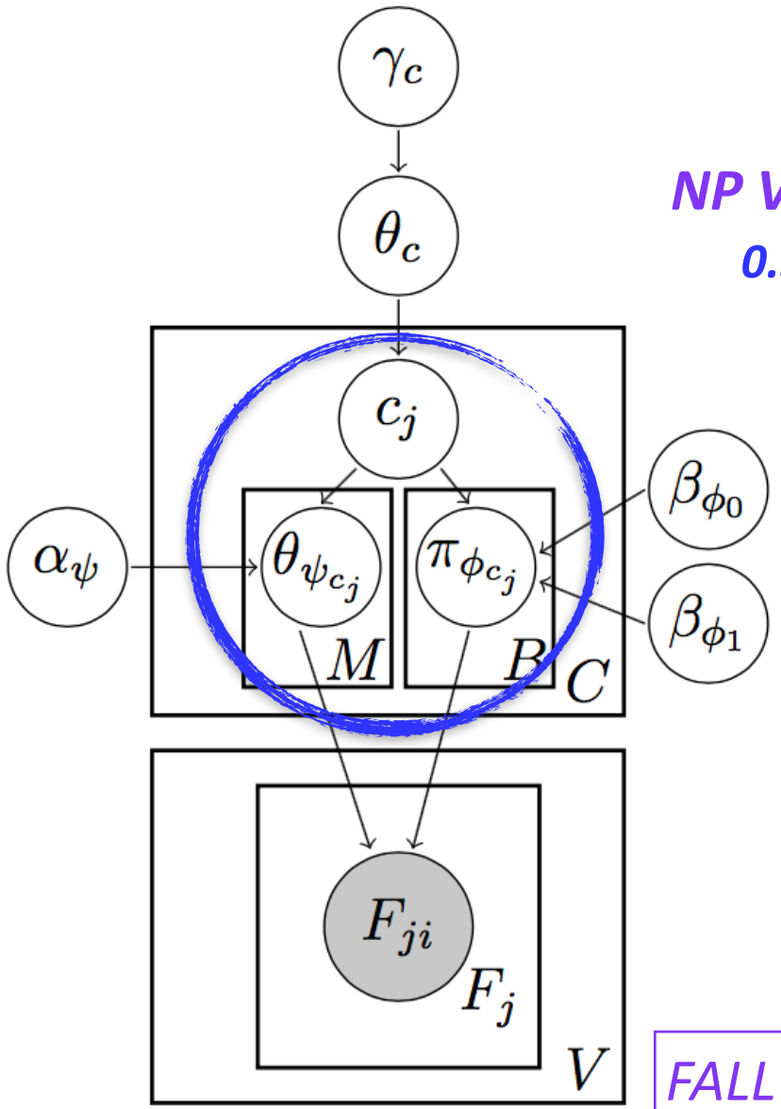
Inference: The learner forms different classes because the characteristics are sufficiently different for each class.

Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**







NP V *…*

NP V PRT *0.25* *NP V S*

0.3 *0*

unaccusatives

+anim *Subject* *-anim*

0.3 *0.7*

FALL

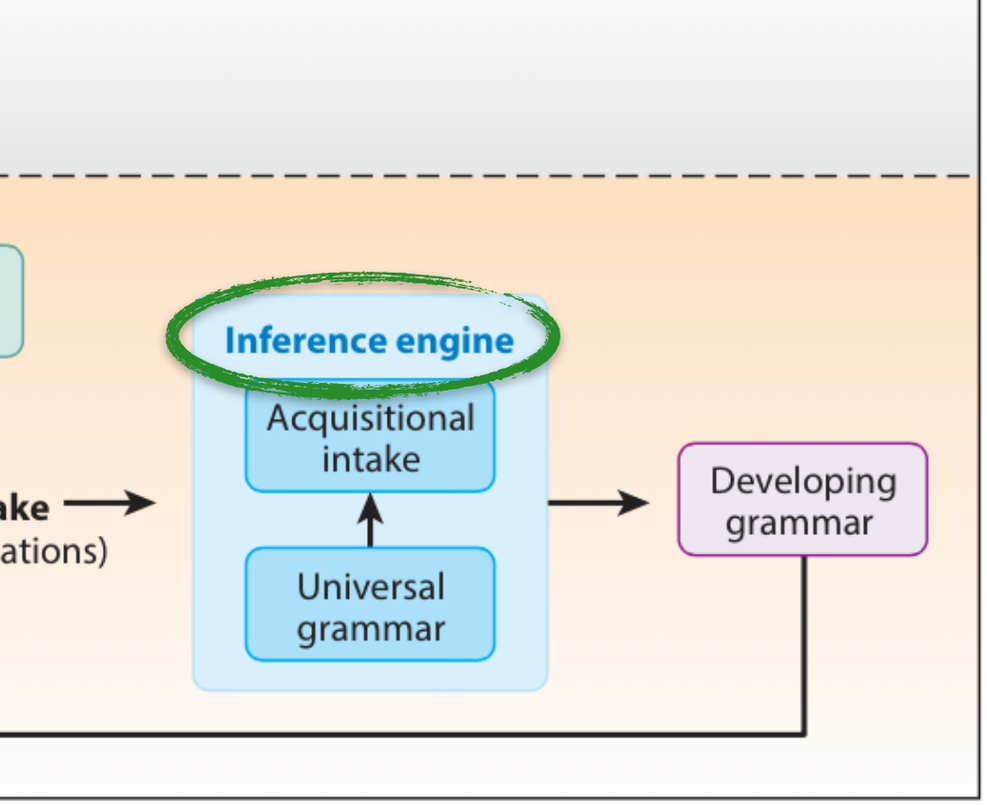
-anim

“it’s falling off”

(3x) *NP V* *PRT*

“it’s falling off”

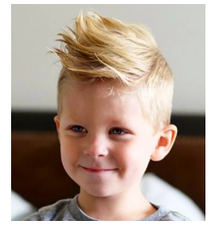
“it’s falling off”



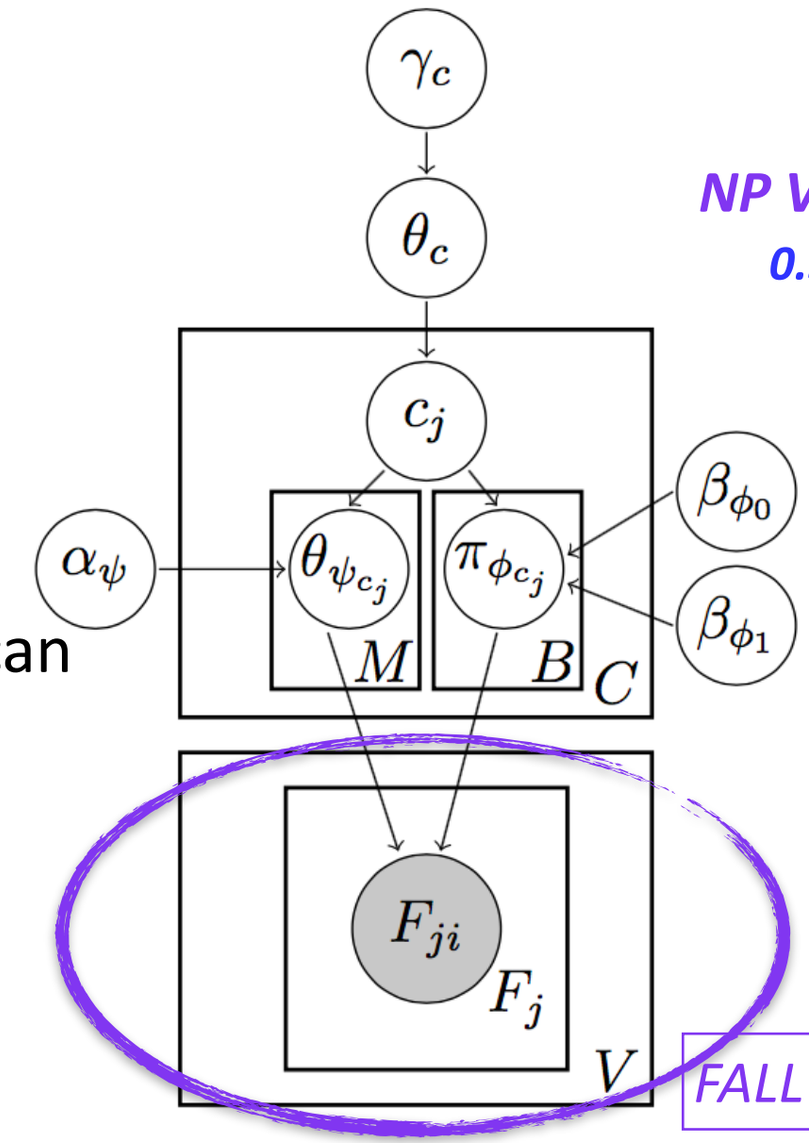
Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





Using the observed instances of verb usage, Bayesian inference can be used to determine …



FALL

NP V *…*

NP V PRT *0.25* *NP V S*

0.3 *0*

unaccusatives

+anim *Subject* *-anim*

0.3 *0.7*

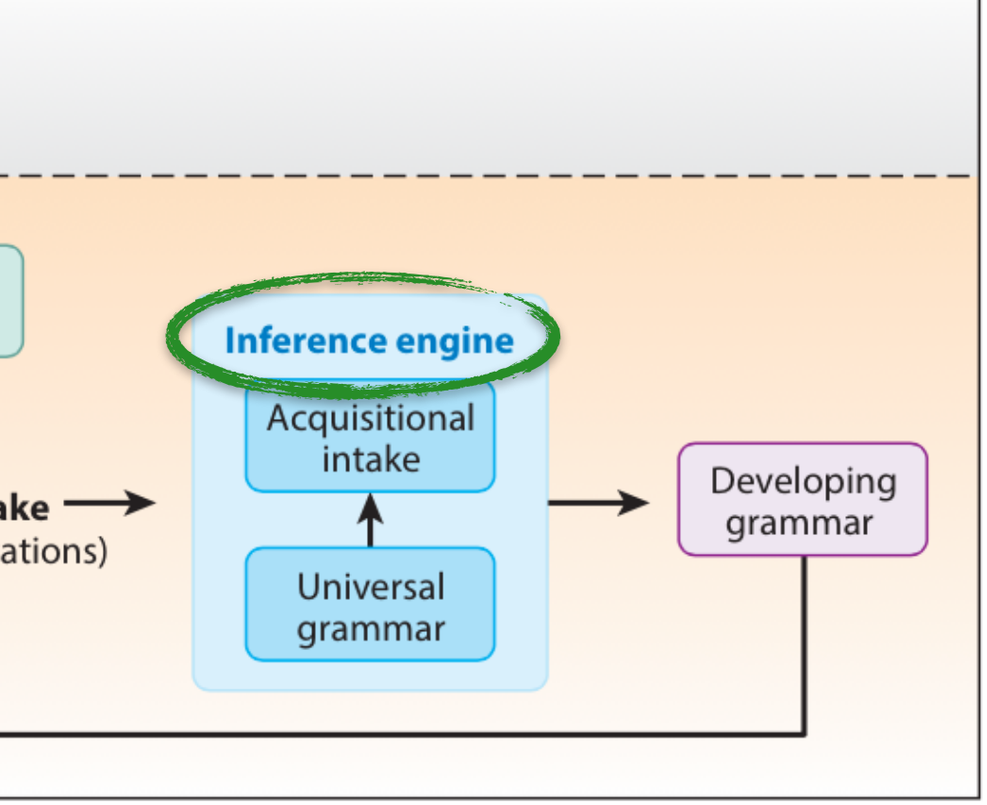
-anim

"it's falling off"

(3x) *NP V* *PRT*

"it's falling off"

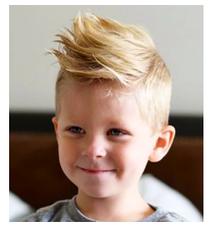
"it's falling off"



Goal: Model the
developmental trajectory
from 3 to 4 to 5 years old

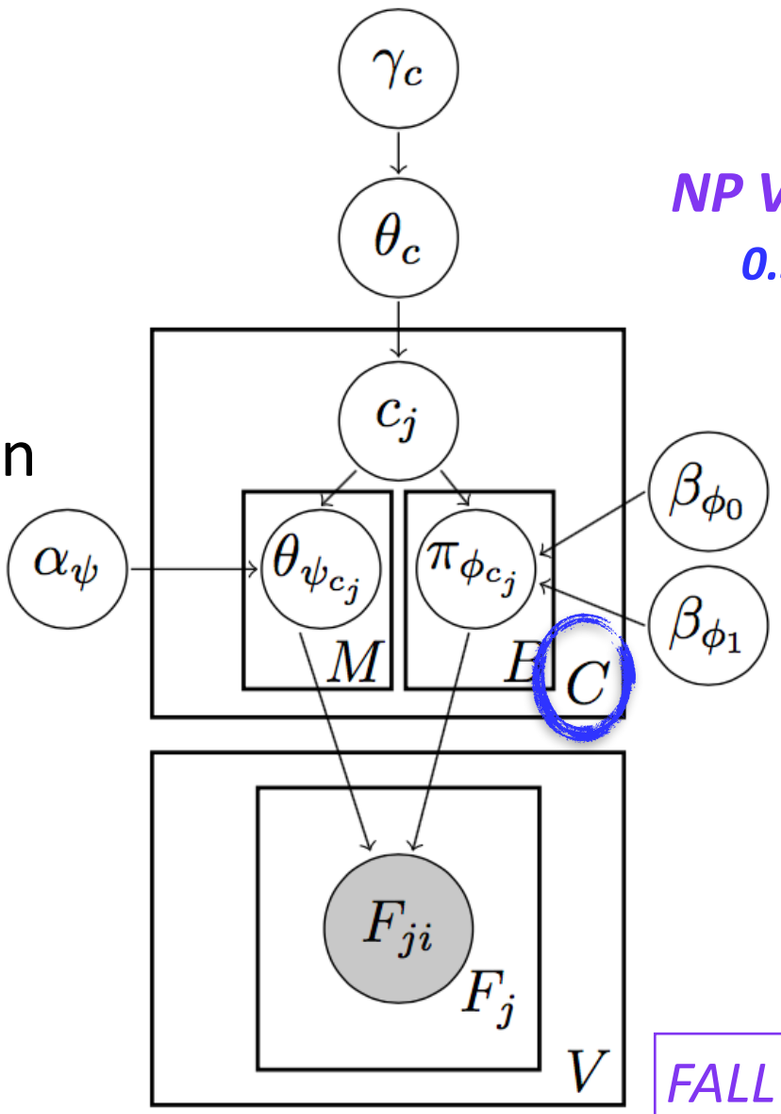
<3yrs **<4yrs** **<5yrs**





Using the observed instances of verb usage, Bayesian inference can be used to determine

- how many classes there are



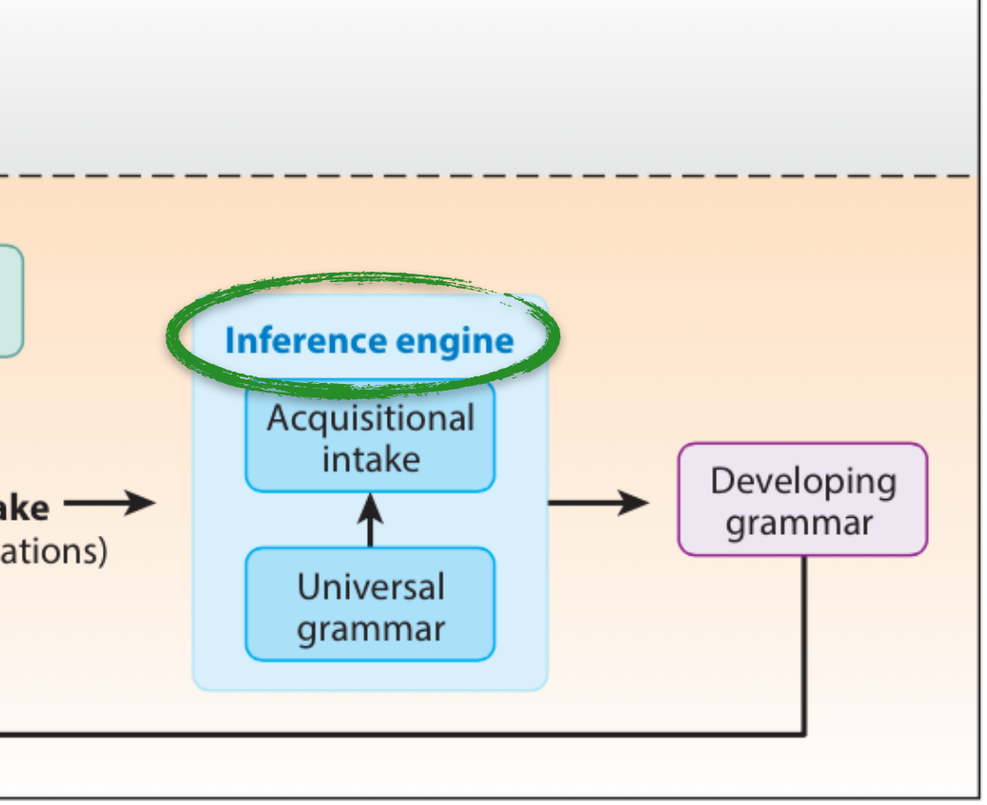
NP V *…*
NP V PRT *0.25* *NP V S*
0.3 *0*

unaccusatives

+anim *Subject* *-anim*
0.3 *0.7*

FALL

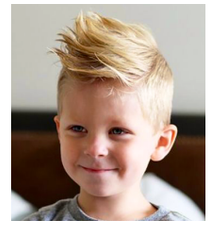
-anim
“it’s falling off”
(3x) *NP V* *PRT*
“it’s falling off”
“it’s falling off”



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

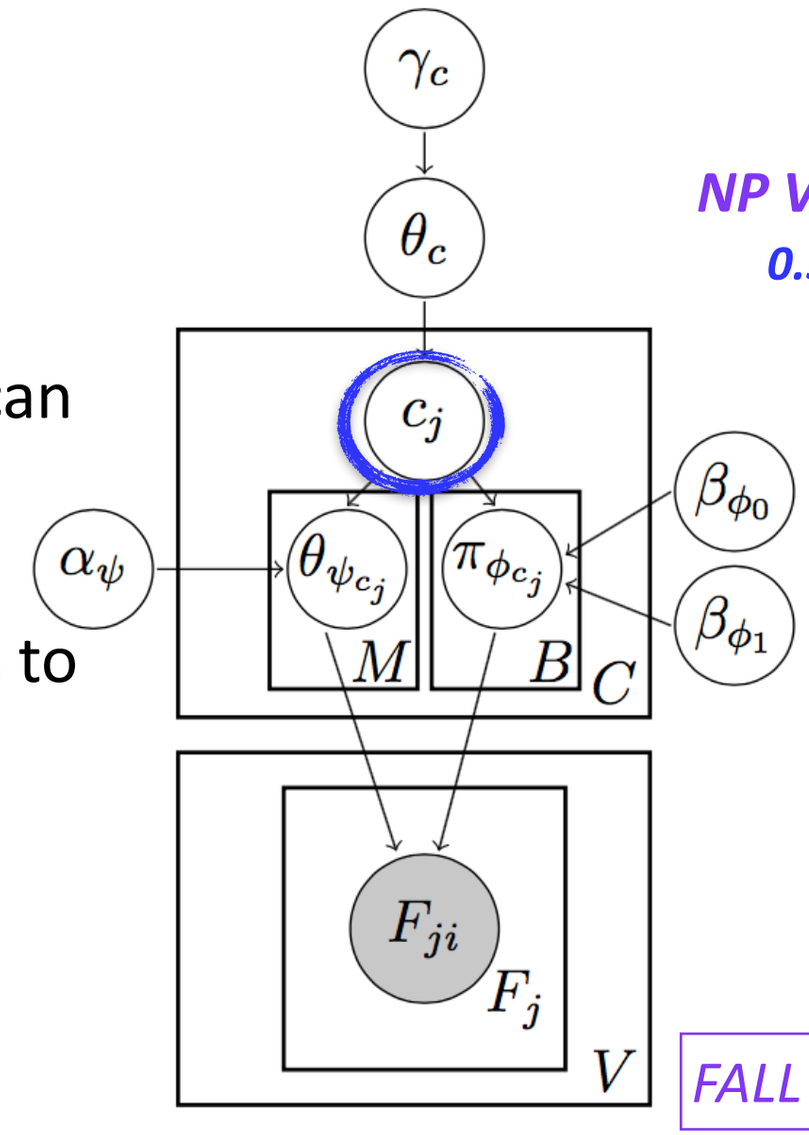
<3yrs **<4yrs** **<5yrs**





Using the observed instances of verb usage, Bayesian inference can be used to determine

- how many classes there are
- which class each verb belongs to



NP V *…*

NP V PRT *0.25* *NP V S*

0.3 *0*

unaccusatives

+anim *Subject* *-anim*

0.3 *0.7*

FALL

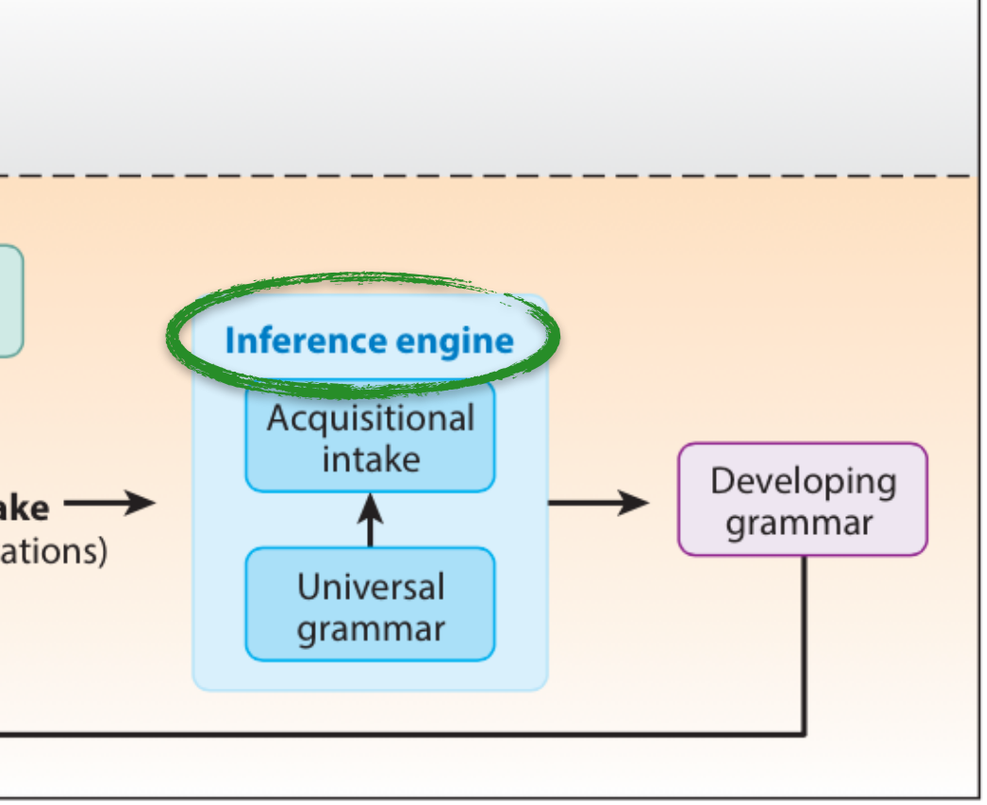
-anim

“it’s falling off”

(3x) *NP V* *PRT*

“it’s falling off”

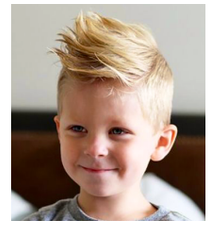
“it’s falling off”



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

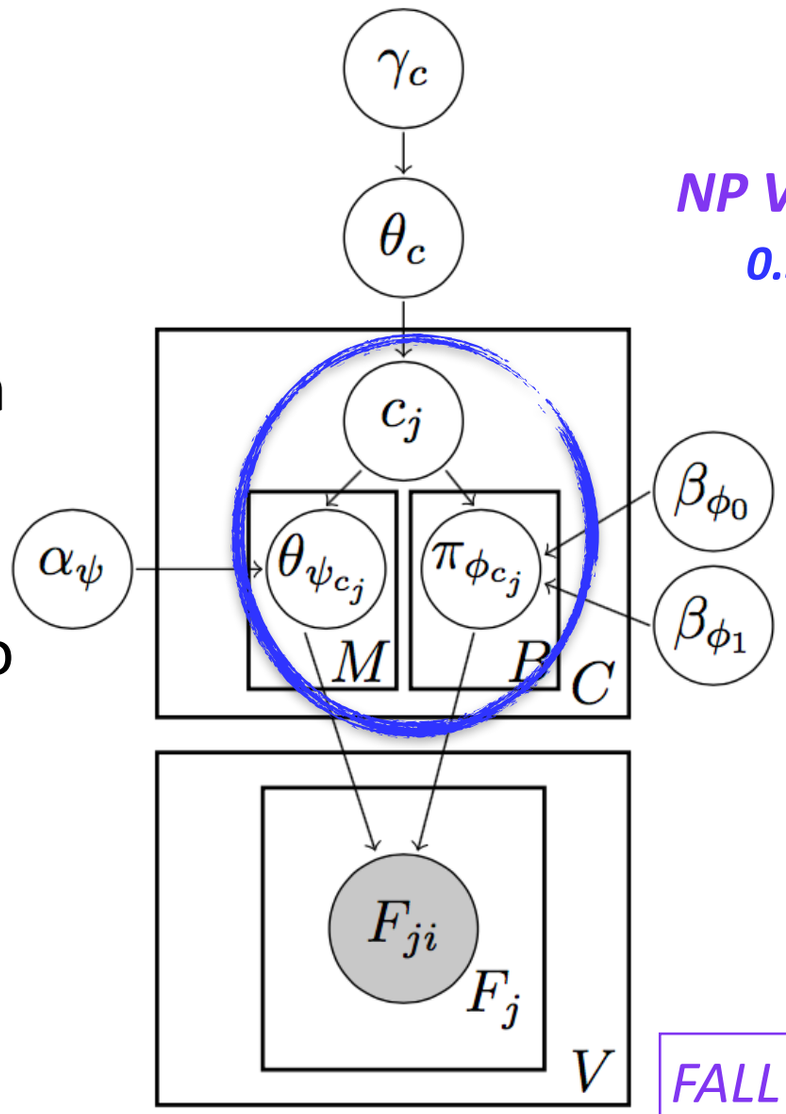
<3yrs **<4yrs** **<5yrs**





Using the observed instances of verb usage, Bayesian inference can be used to determine

- how many classes there are
- which class each verb belongs to
- what the characteristics are of each class



NP V *…*

NP V PRT *0.25* *NP V S*

0.3 *0*

unaccusatives

+anim *Subject* *-anim*

0.3 *0.7*

FALL

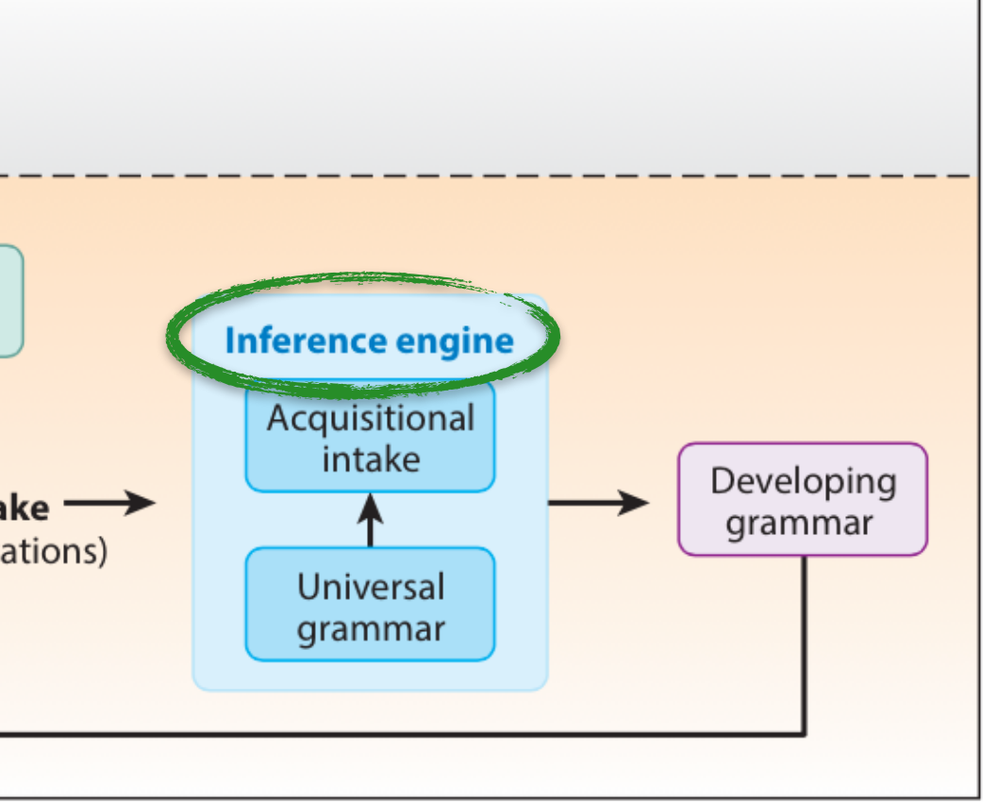
-anim

"it's falling off"

(3x) *NP V* *PRT*

"it's falling off"

"it's falling off"



Using the observed instances of verb usage, Bayesian inference can be used to determine

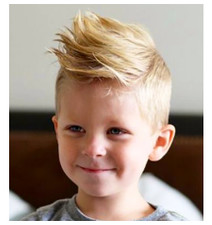
- how many classes there are
- which class each verb belongs to
- what the characteristics are of each class

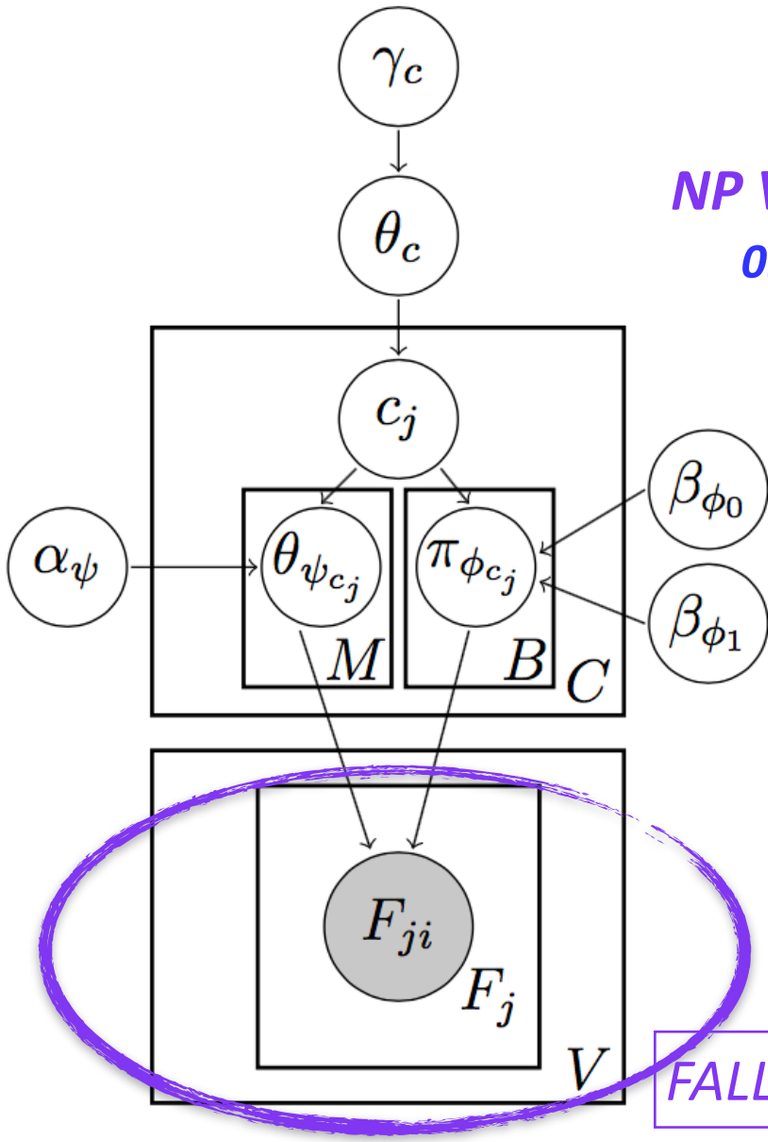
Best answer: maximizes the probability of the observed data.

Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**







FALL

NP V …

NP V PRT *0.25* *NP V S*

0.3 *0*

unaccusatives

+anim *Subject* *-anim*

0.3 *0.7*

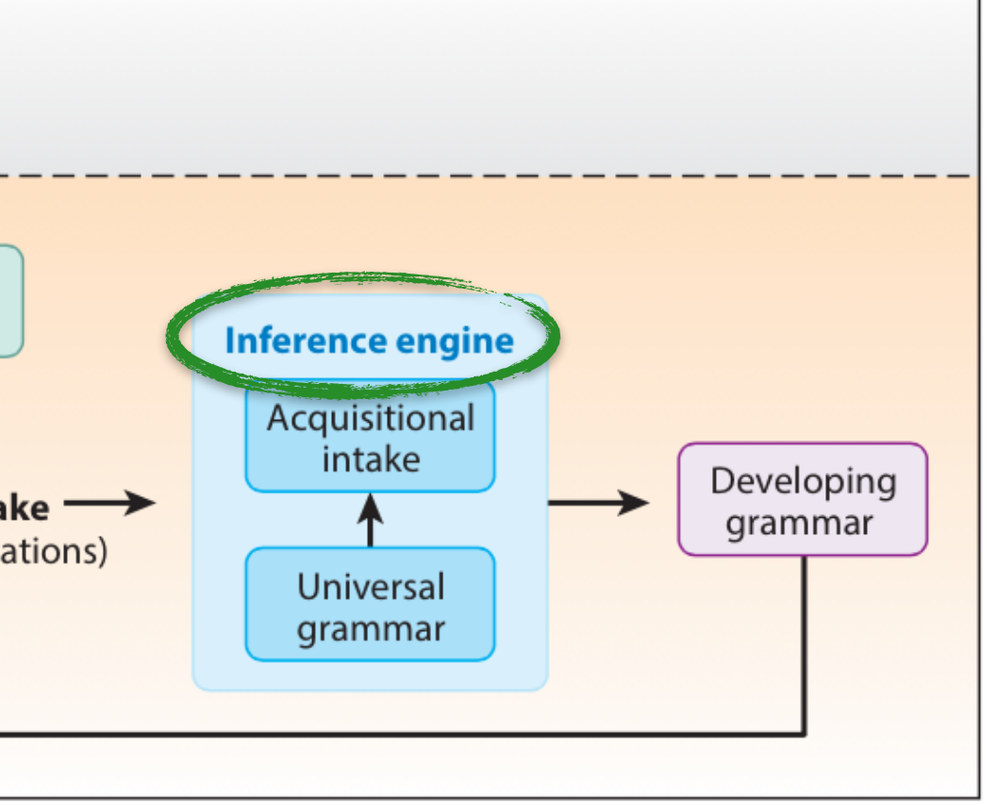
-anim

"it's falling off"

(3x) *NP V* *PRT*

"it's falling off"

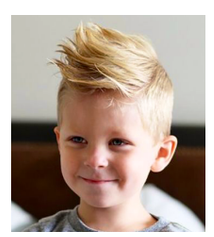
"it's falling off"



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



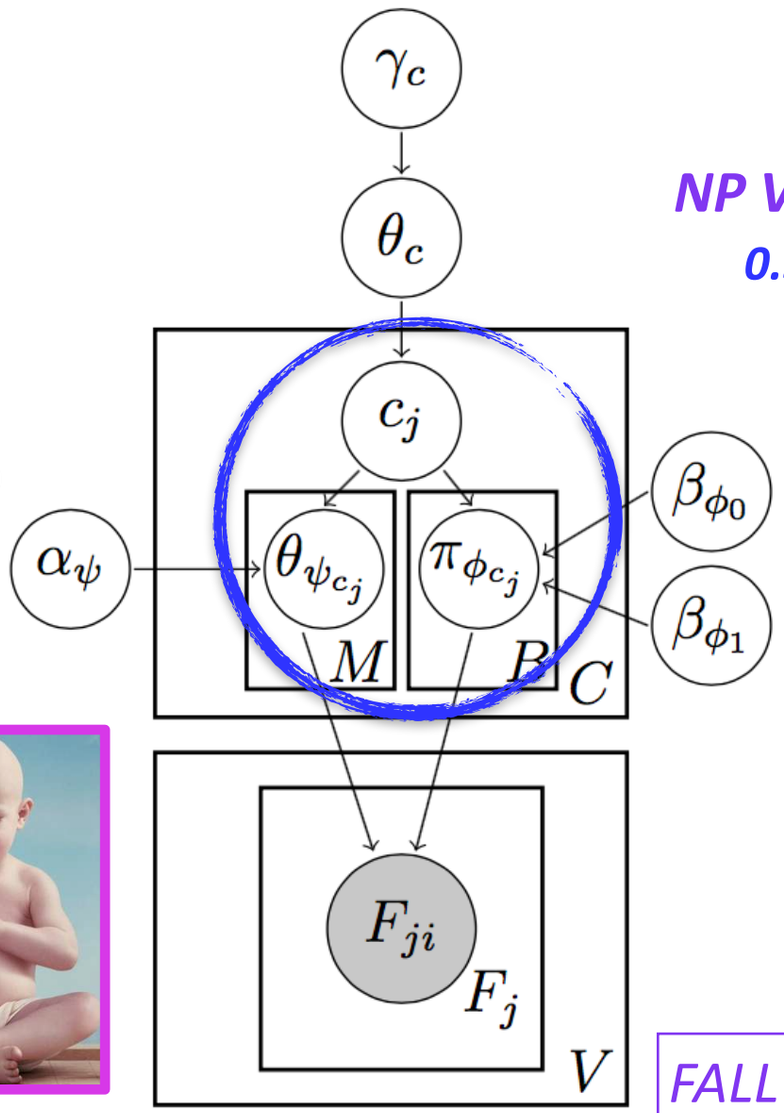


Using the observed instances of verb usage, Bayesian inference can be used to determine

- how many classes there are
- which class each verb belongs to
- what the characteristics are of each class

$$p_{c_j} = P(c_j|c_{-j}, \gamma_c, F_{-j}, \lambda) = p_{cat_j} * p_{binary_{c_j}} * p_{multinomial_{c_j}}$$

+ Gibbs sampling (method guaranteed to find optimal answer, given sufficient time to search the hypothesis space)



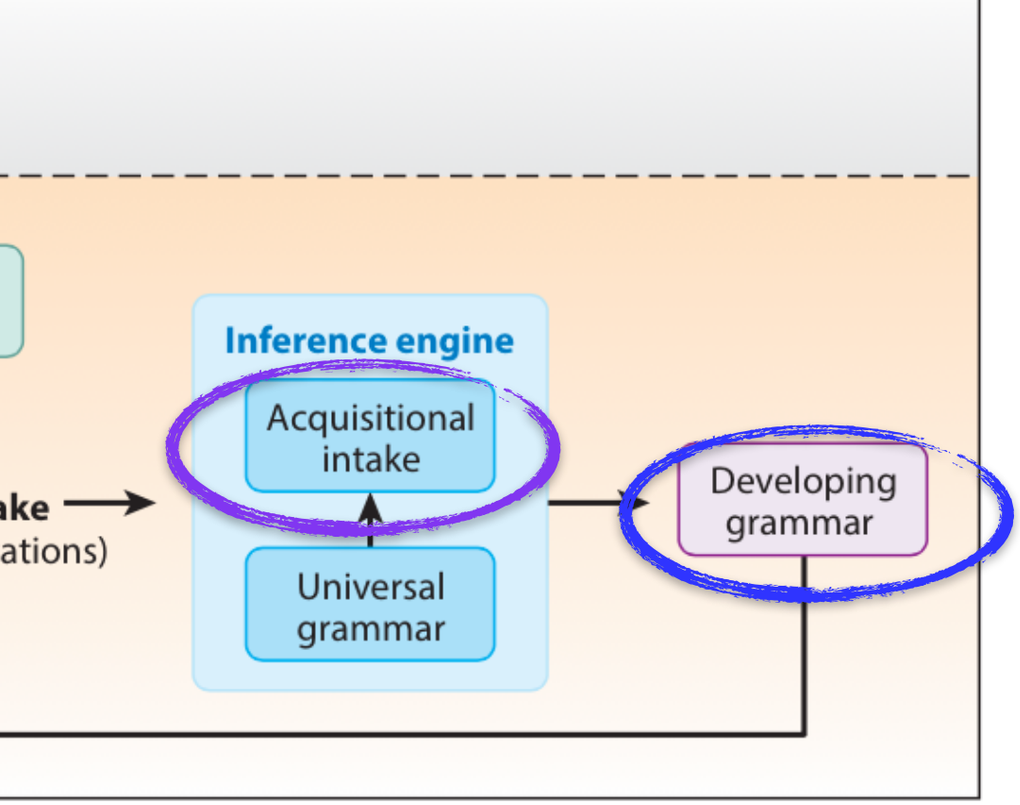
	NP V	…
NP V PRT	0.25	NP V S
0.3		0

unaccusatives

+anim	Subject	-anim
0.3		0.7

FALL

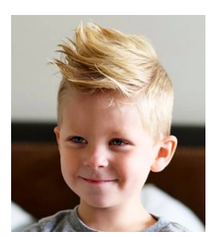
-anim
"it's falling off"
(3x) NP V PRT
"it's falling off"
"it's falling off"



Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





Goal: Determine if the information provided in the acquisitional intake is sufficient to identify verb classes this way.

+surfmorph

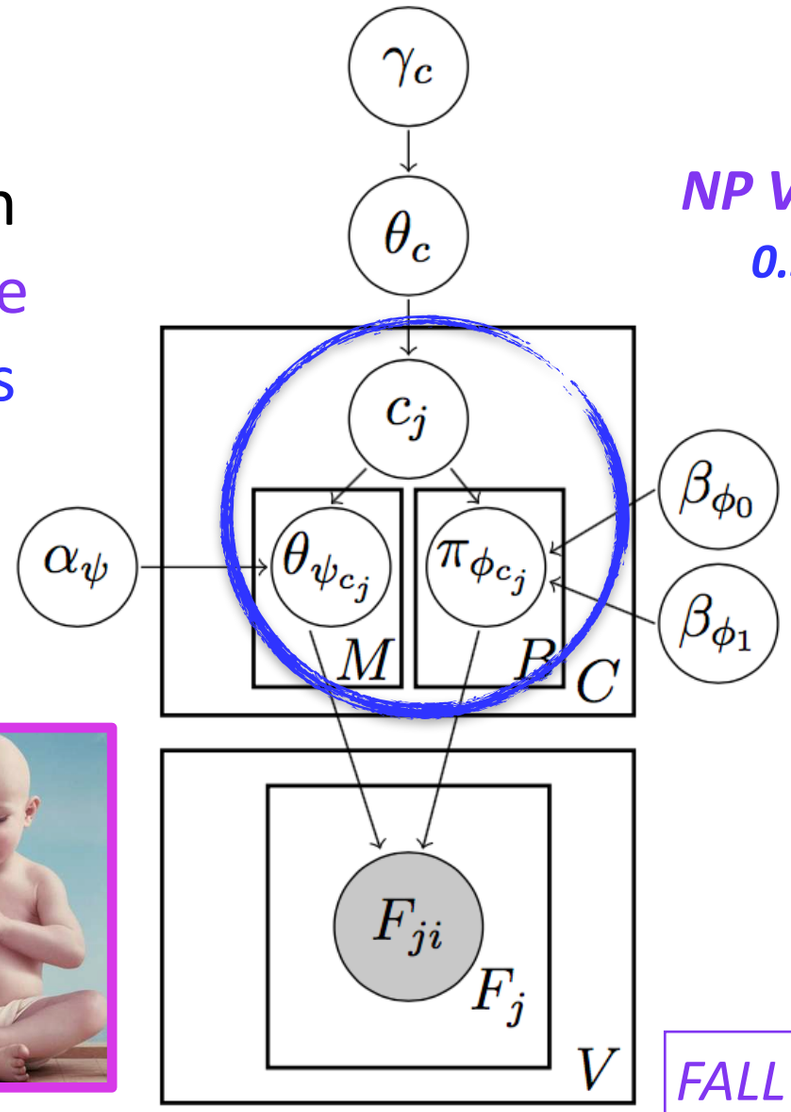
-surfmorph

UTAH

rUTAH

-expmap

+expmap



NP V *…*

NP V PRT *0.25* *NP V S*

0.3 *0*

unaccusatives

+anim *Subject* *-anim*

0.3 *0.7*

FALL

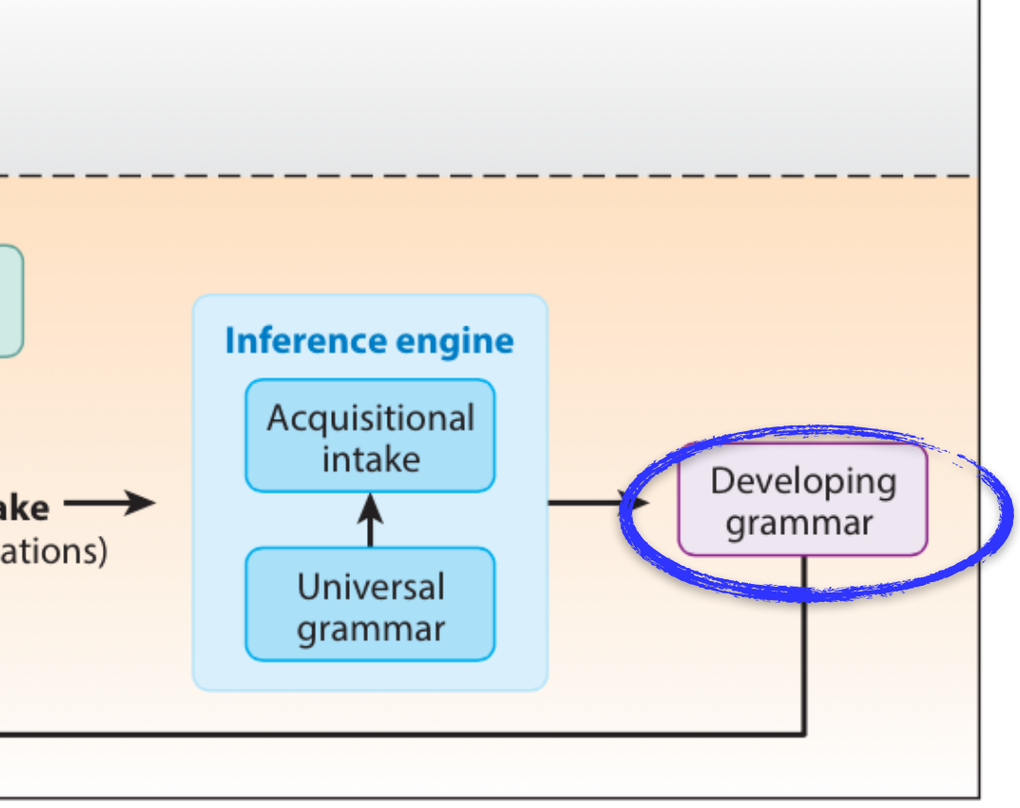
-anim

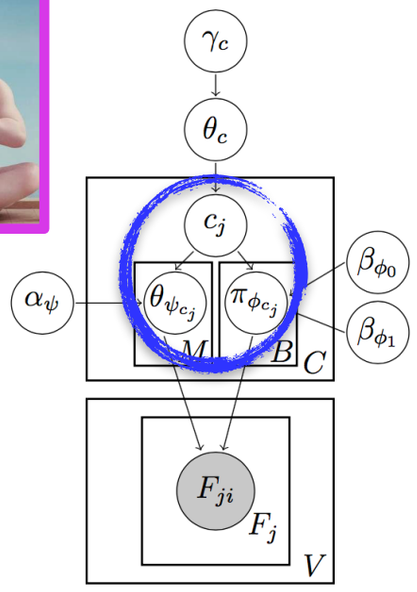
“it’s falling off”

(3x) *NP V* *PRT*

“it’s falling off”

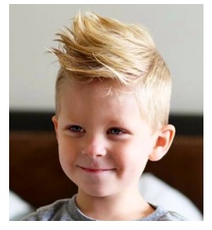
“it’s falling off”



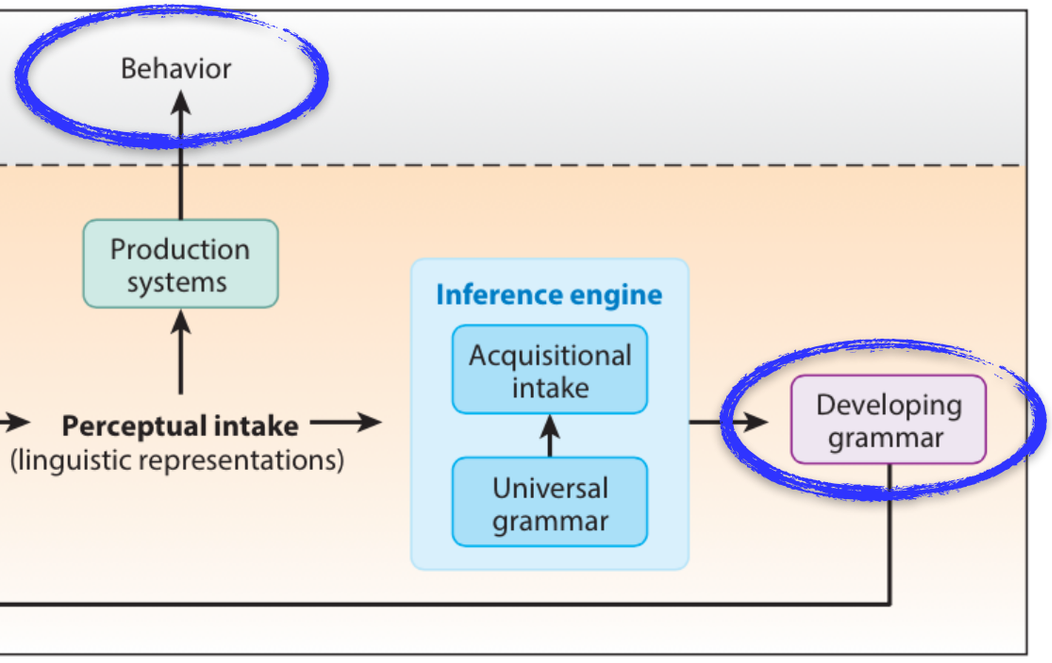


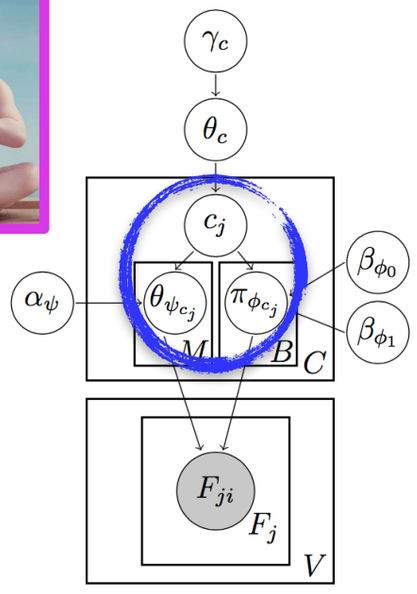
Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



verb classes





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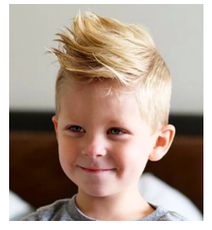
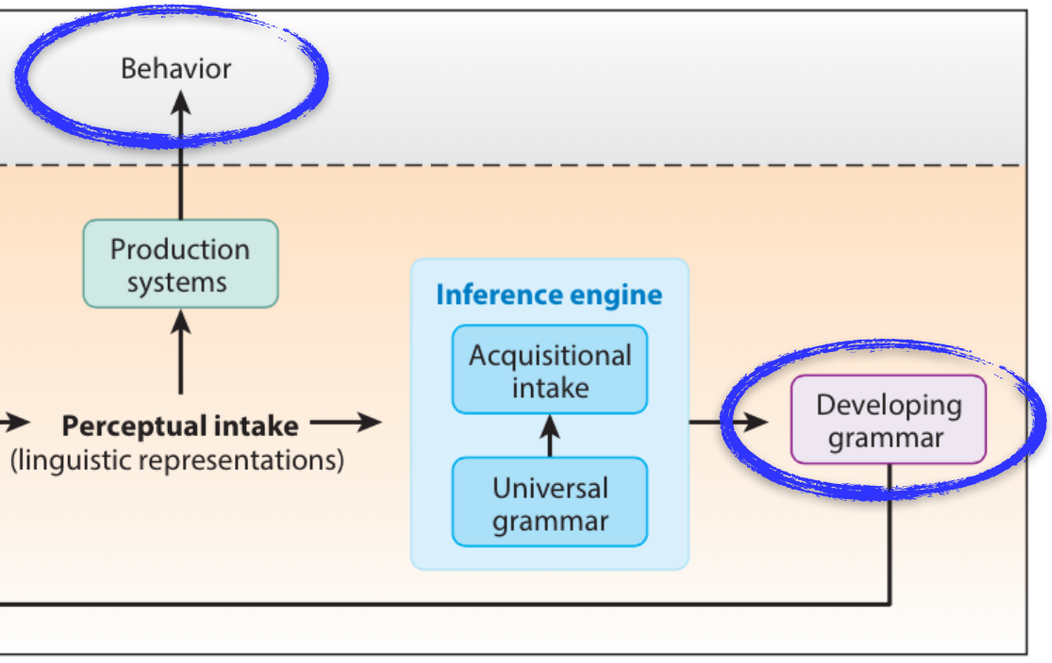
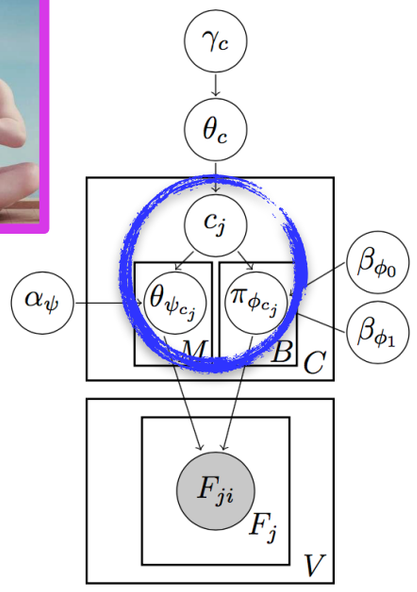


verb classes

Survey of **32** experimental studies on children's production and comprehension of specific verbs

Yields 12 verb behaviors





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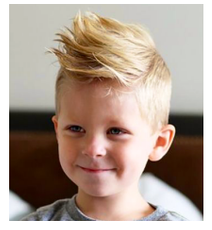

verb classes

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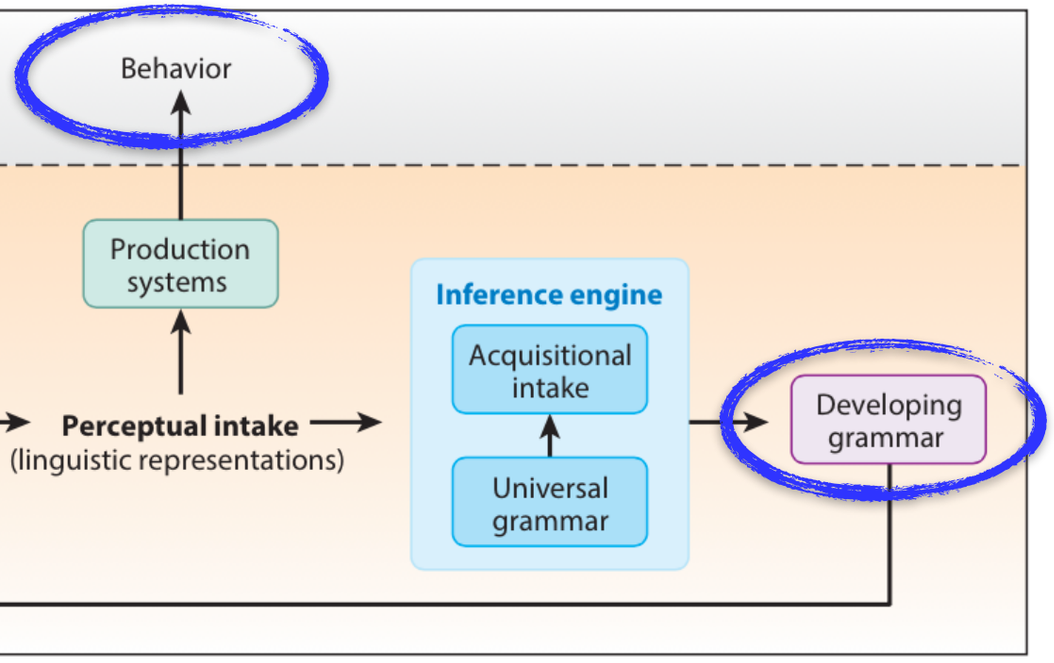
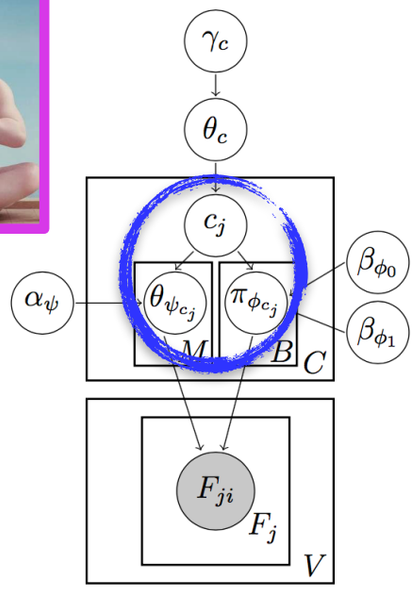
Passives: Maratsos 1974, Maratsos et al. 1985, Gordon & Chafetz 1990, O'Brien et al. 2006, Crain et al. 2009, Messenger et al. 2009, Nguyen et al. 2016

"It was ___-en."
done-to





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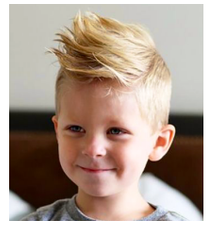
<4yrs **<5yrs**



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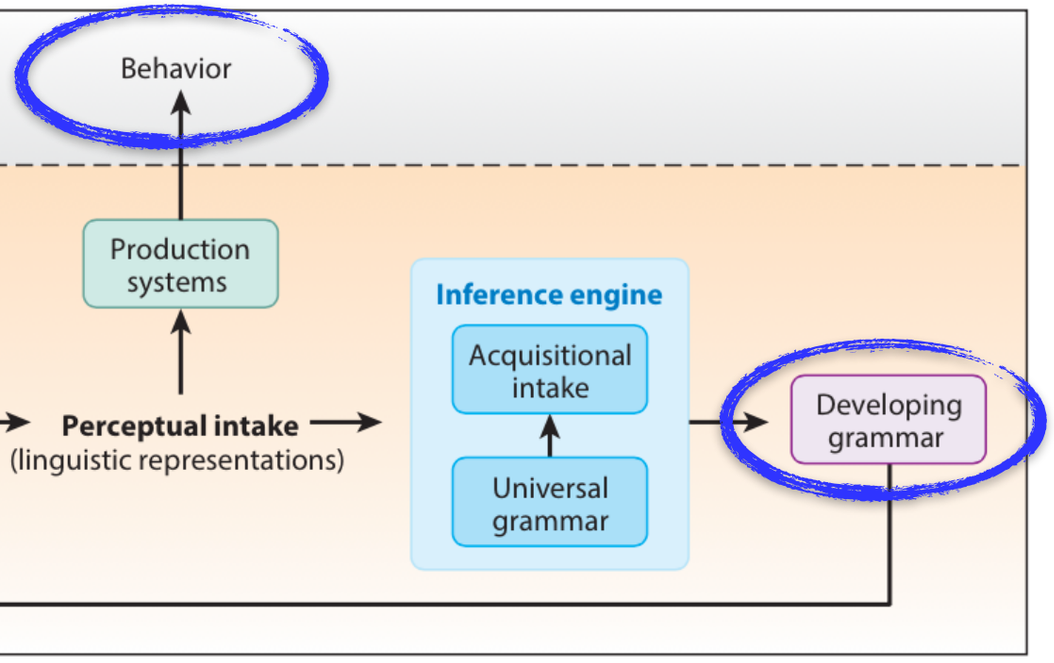
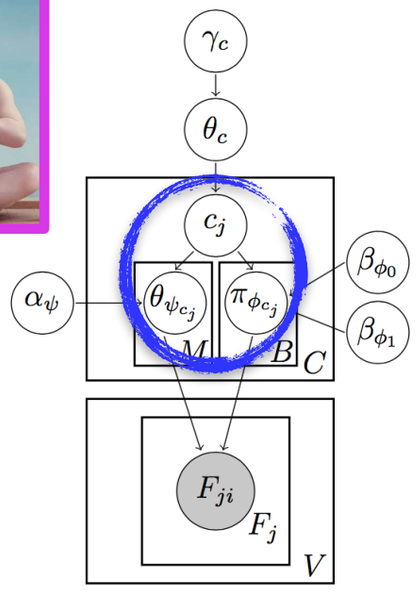
"It was ___-en."
done-to

3yrs

+= hit, see, …

-= know, remember, …

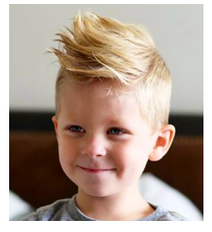




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs

<5yrs



verb classes

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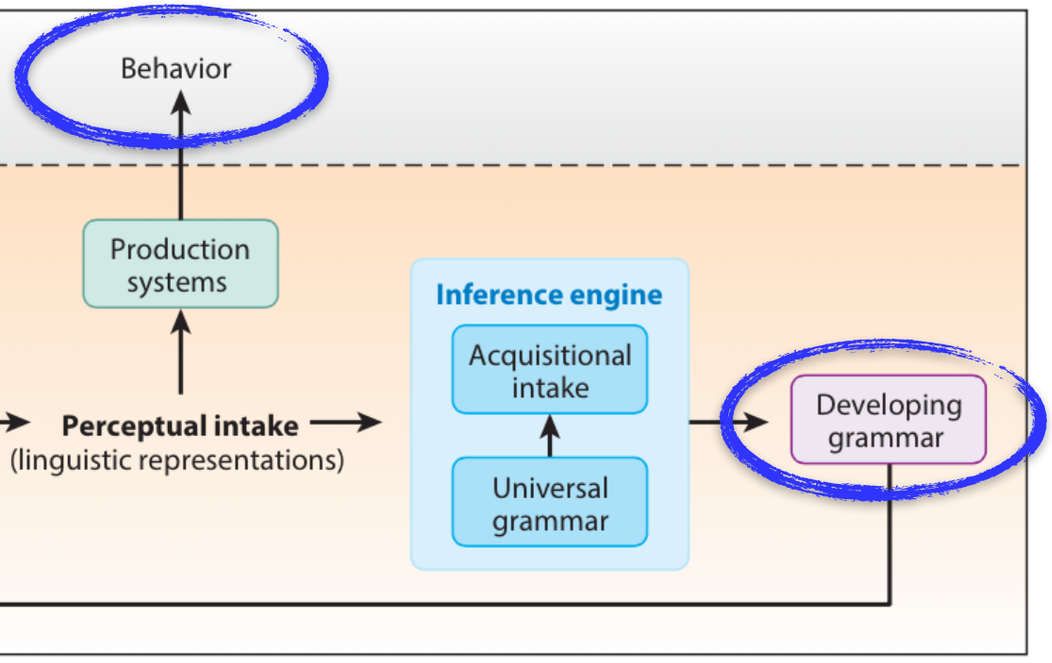
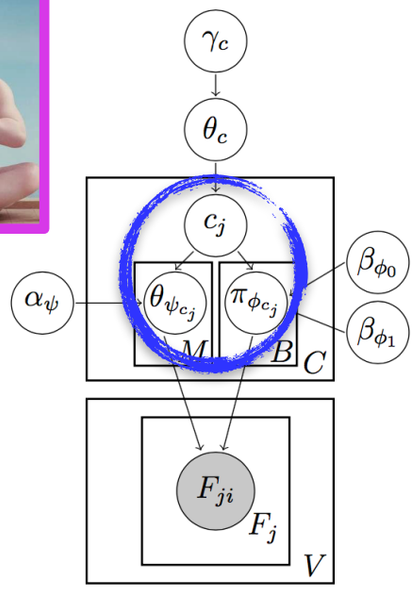
"It was ___-en."
done-to

4yrs

+= hit, scare, see, …

-= know, love, remember, …





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<3yrs **<4yrs**

verb classes

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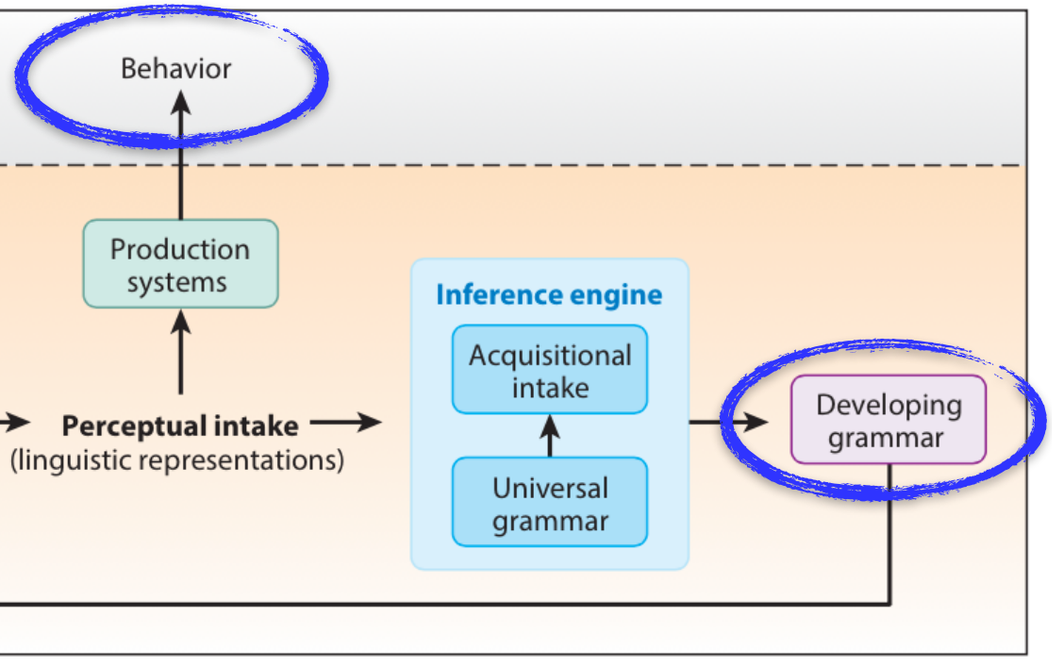
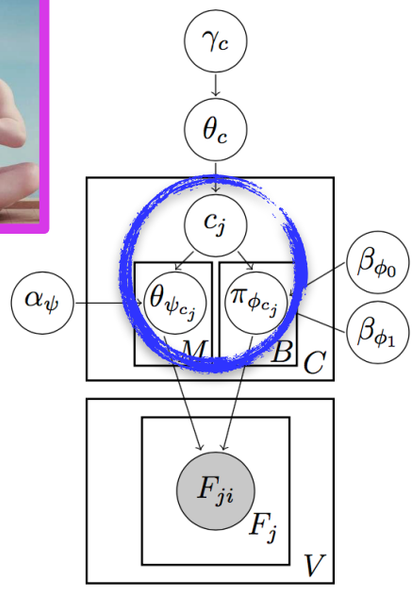
"It was ___-en."
done-to

5yrs

+= hit, love, scare, see, …

-= know, remember, …





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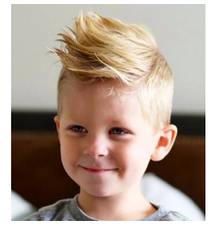
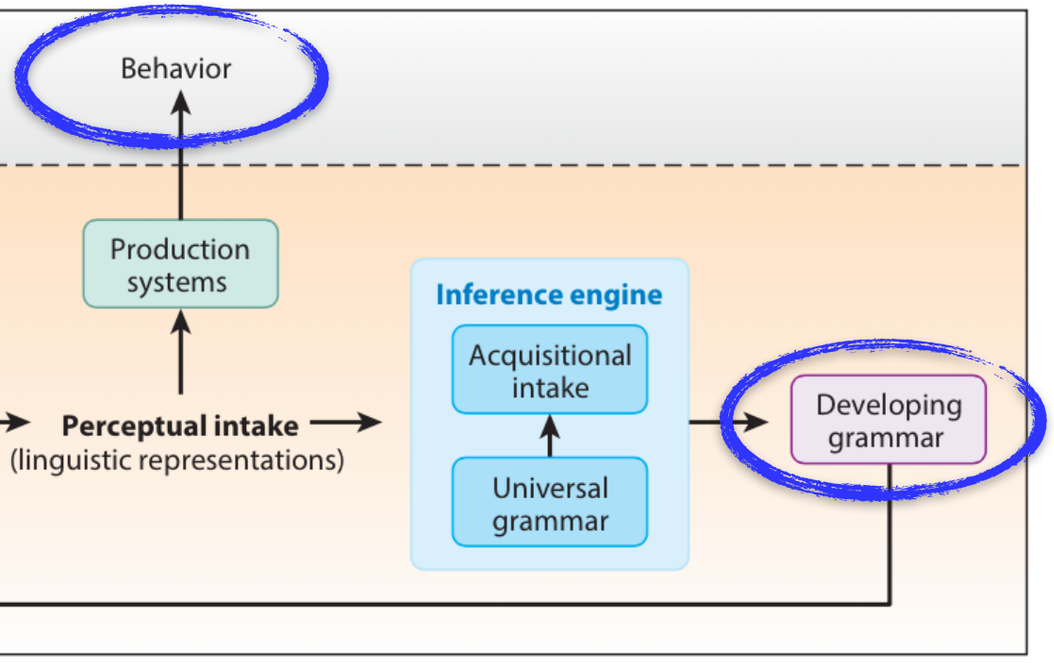


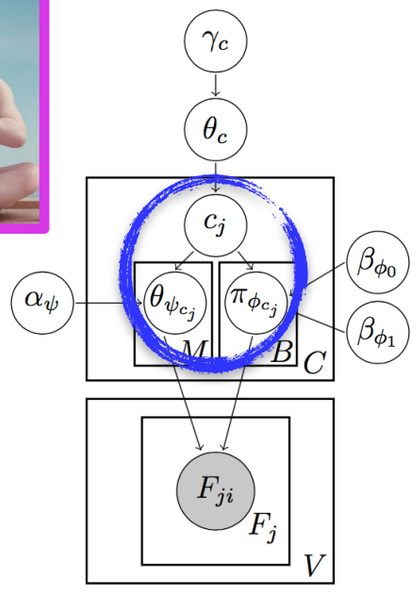
verb classes

Survey of **32** experimental studies on children's production and comprehension of specific verbs

Ditransitives: Gropen et al. 1989, Snedeker & Huang in press, Campbell & Tomasello 2001, Huttenlocher et al. 2004, Conwell & Demuth 2007, Thothathiri & Snedeker 2008

"Jack ___ Lily the thing."





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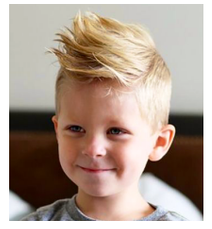

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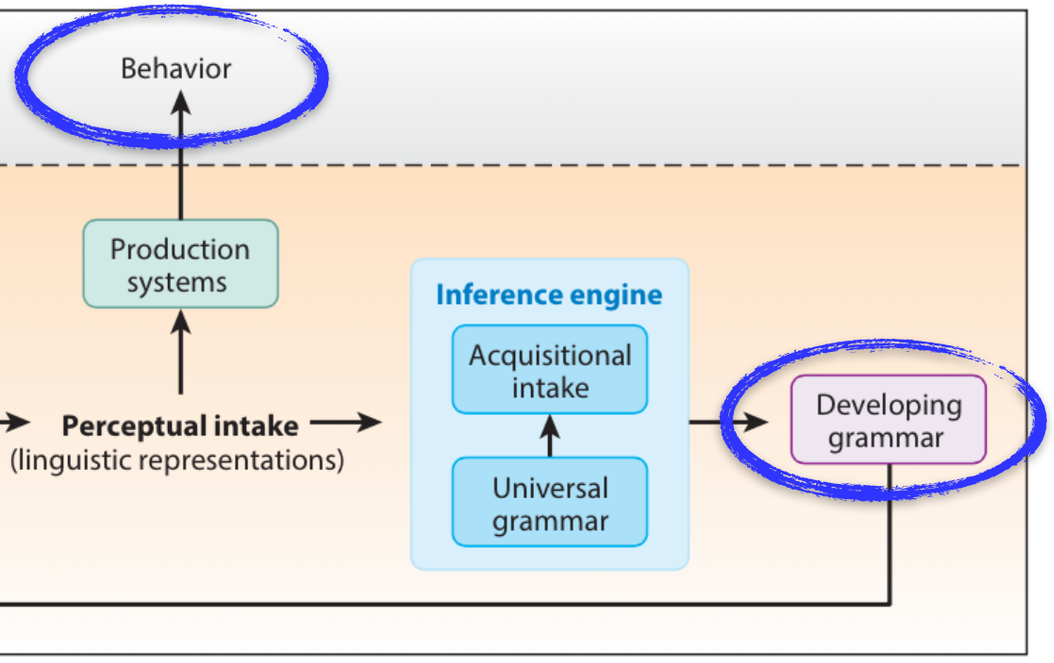
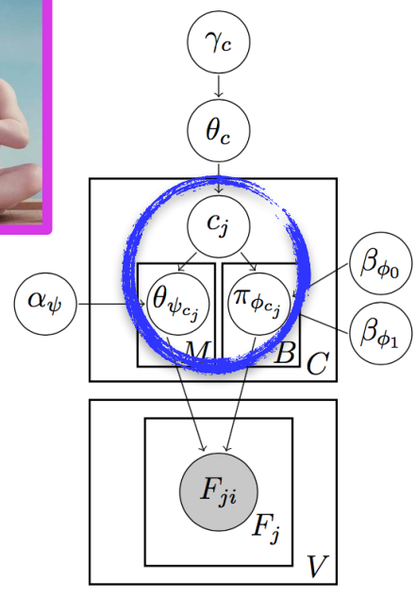
"Jack ___ Lily the thing."

3yrs

+= give, read, *say, …

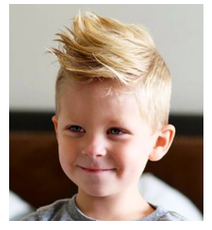




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs

<5yrs



verb classes

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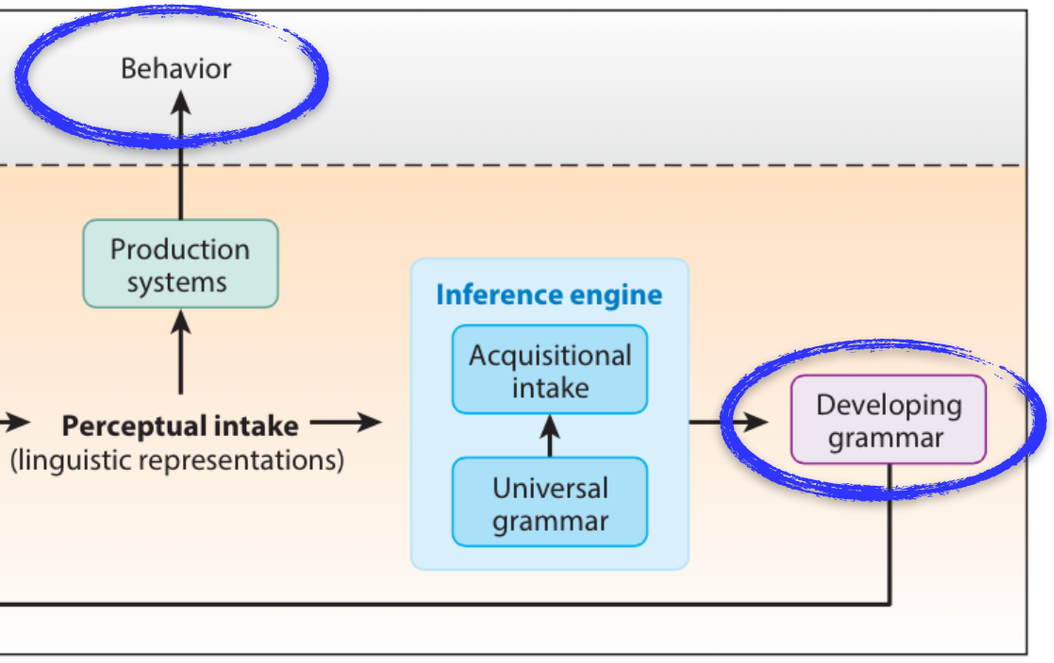
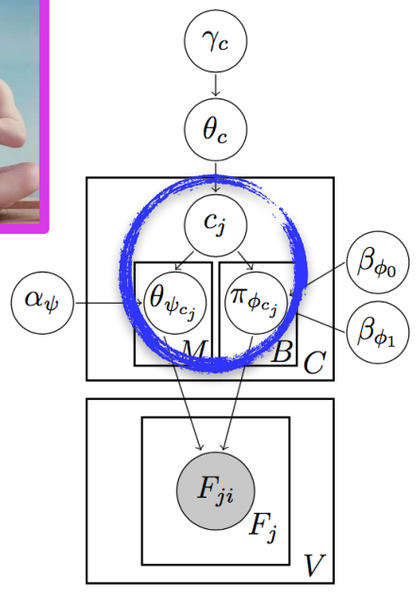
"Jack ___ Lily the thing."

4yrs

+= give, read, *say, teach, …





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs

<4yrs

verb classes

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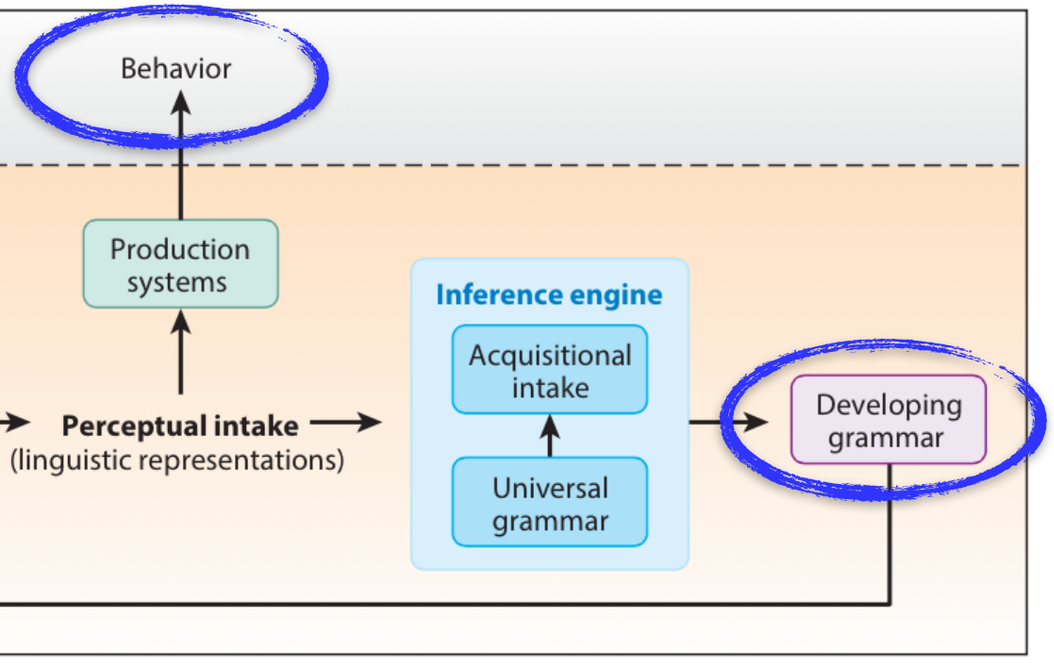
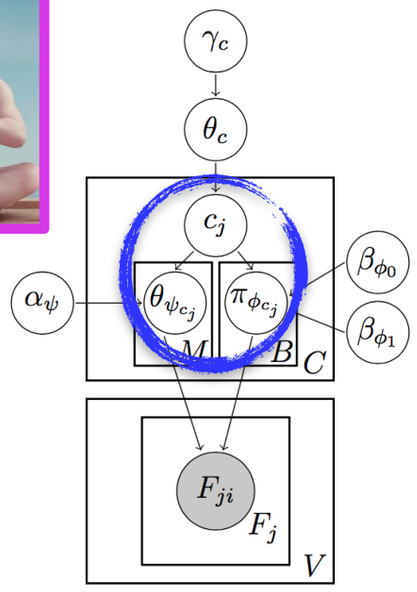
"Jack ___ Lily the thing."

5yrs

+= ask, give, read, *say, teach, …





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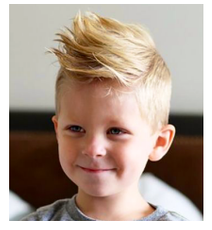
<3yrs **<4yrs** **<5yrs**





verb classes

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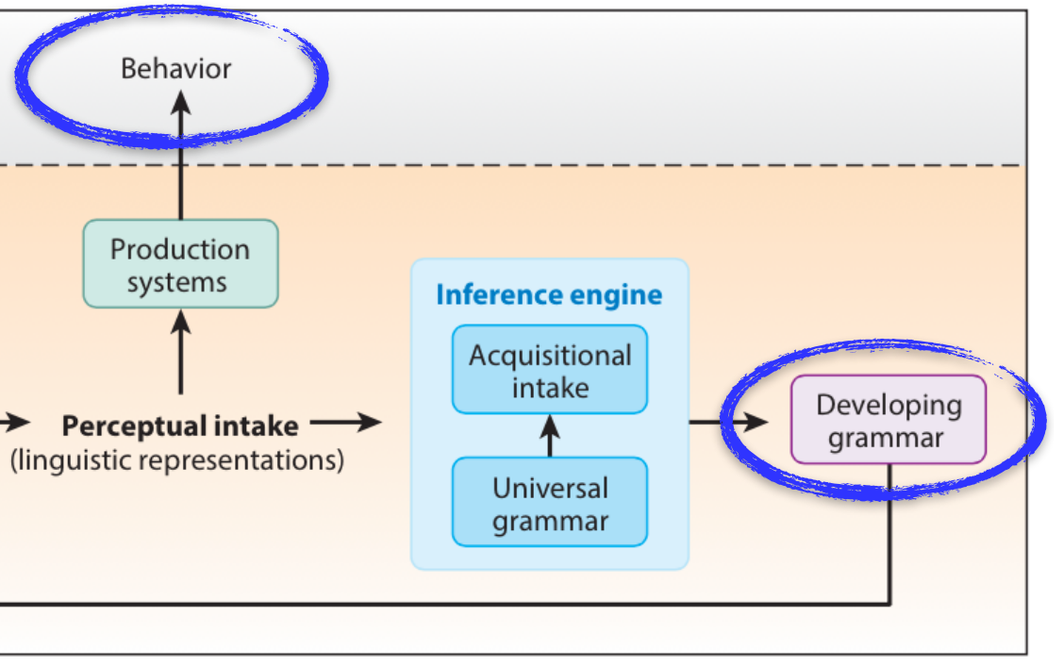
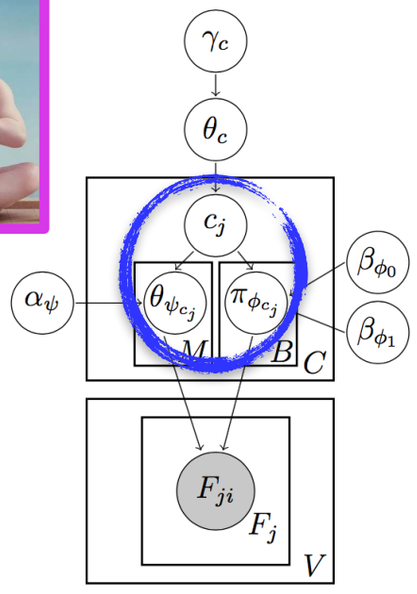
"It ____."
done-to





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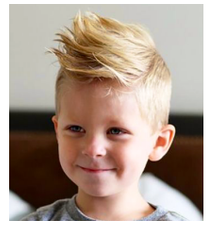

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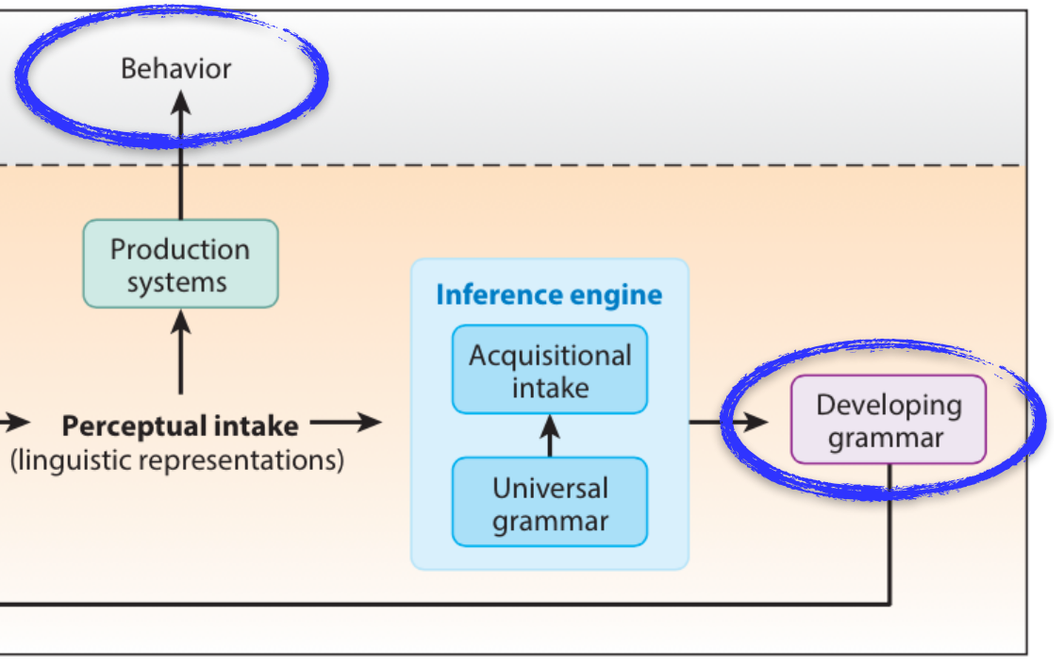
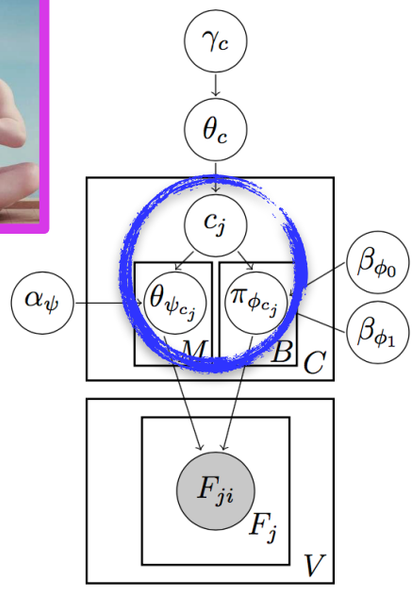
"It ____."
done-to

3yrs

+= break, fall, …





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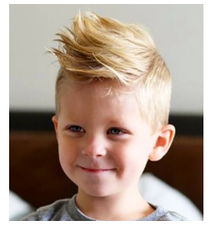
<3yrs **<4yrs** **<5yrs**





verb classes

Survey of **32** experimental studies on children's production and comprehension of specific verbs

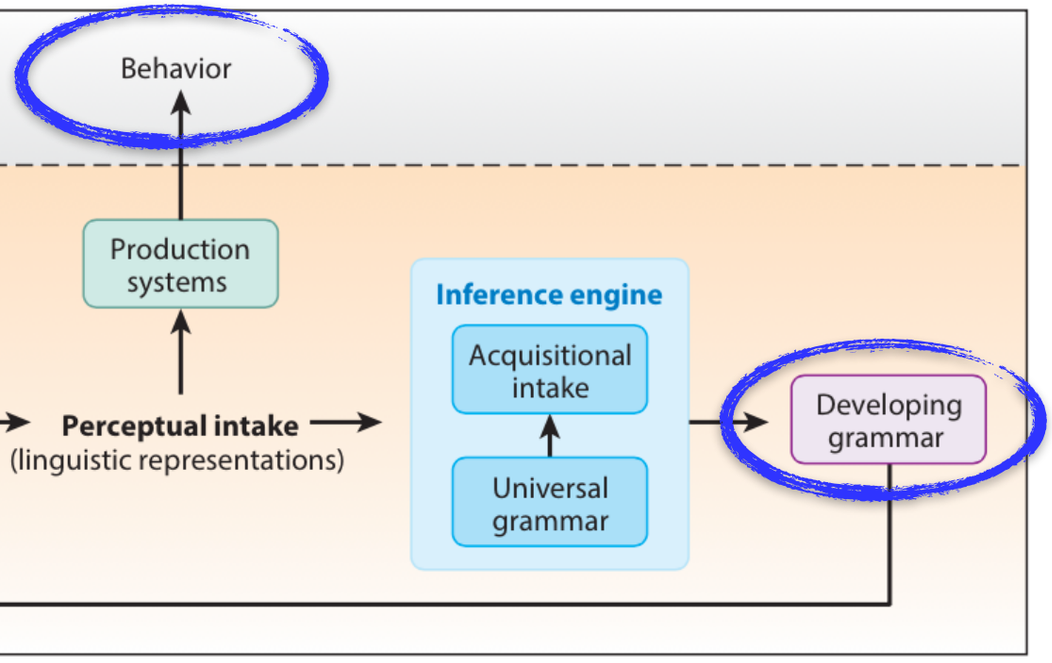
Control object & Raising object: Kirby 2009a, Kirby 2009b, Kirby 2010, Becker 2014

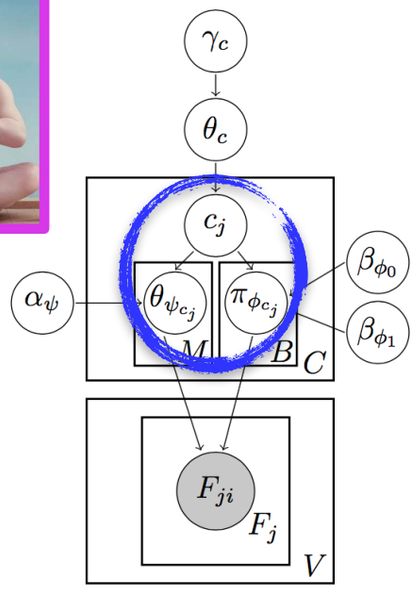
Control object

"I ___him to leave."

done-recipient (main)

doer (embedded)





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<3yrs

verb classes

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done-recipient (main)

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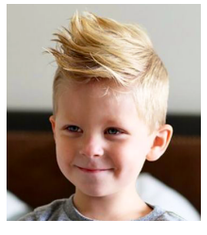
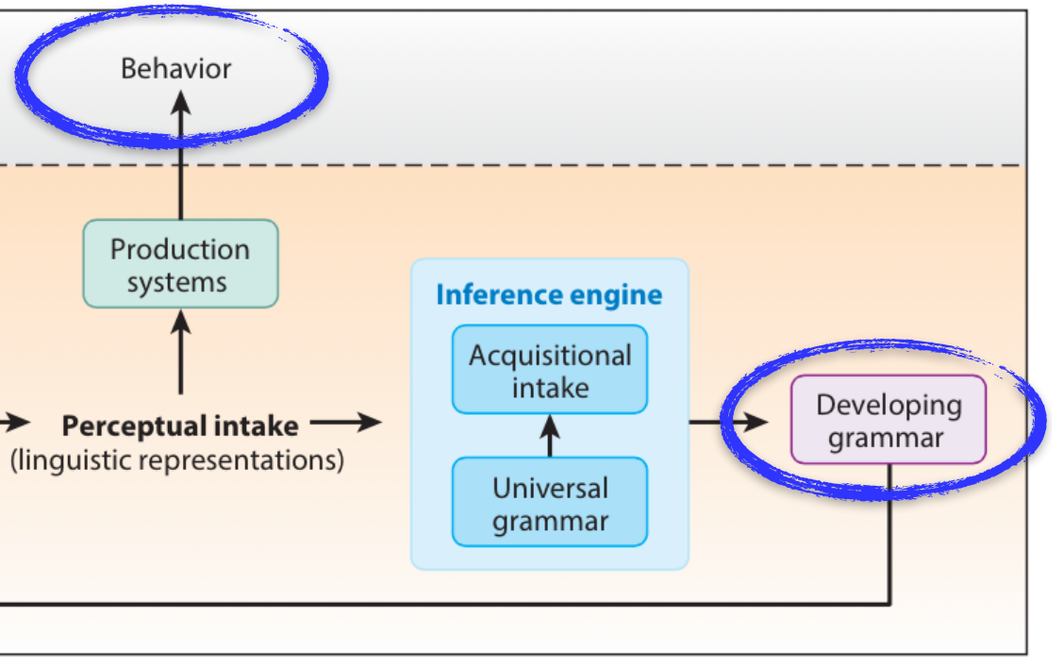
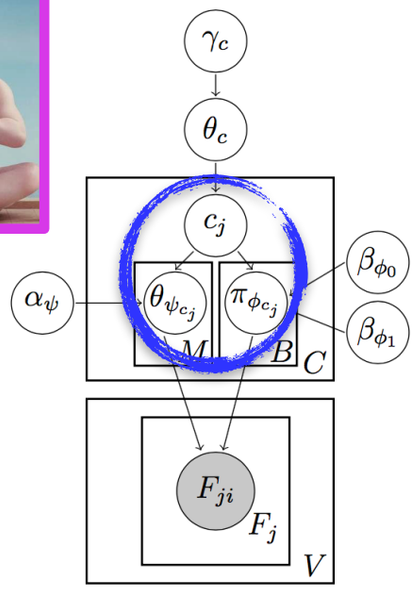
4yrs

5yrs



+= ask, tell





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<3yrs

verb classes

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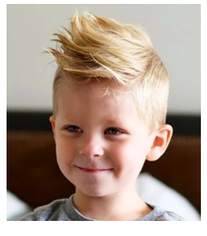
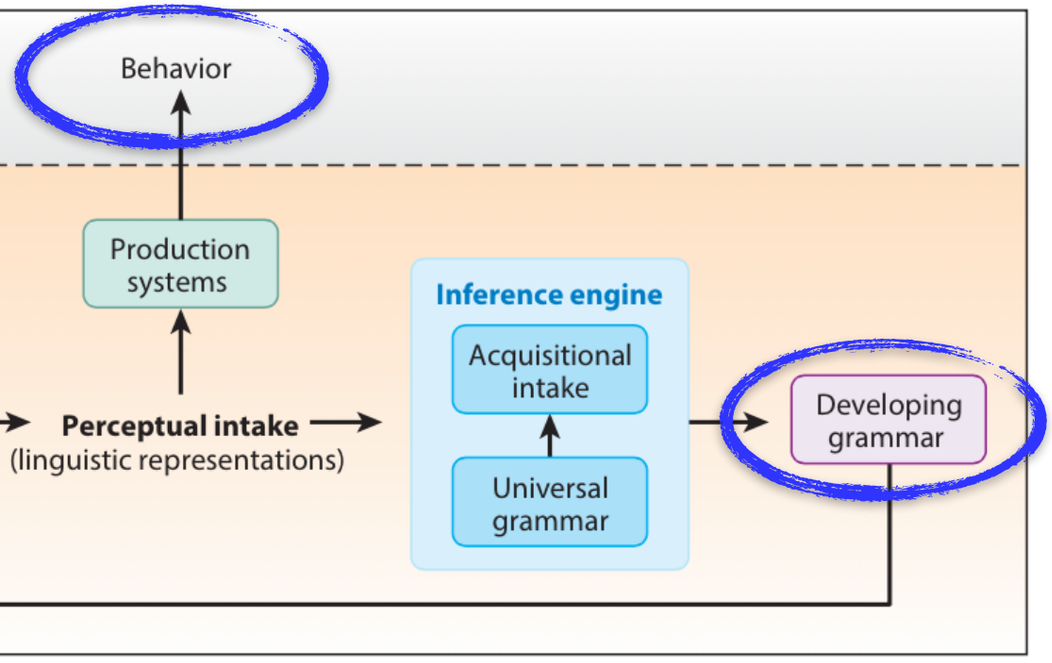
Raising object

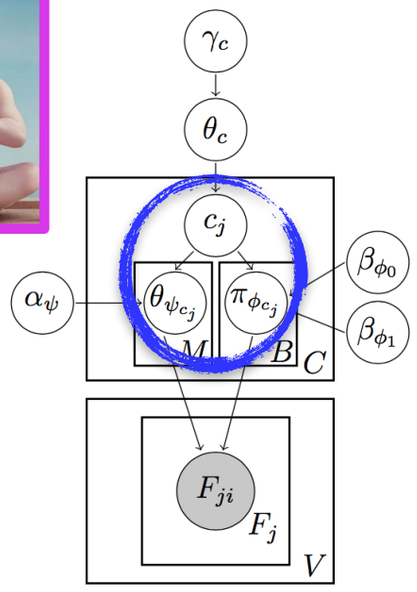
"I ___him to leave."
doer (embedded)

4yrs **5yrs**



+= need, want

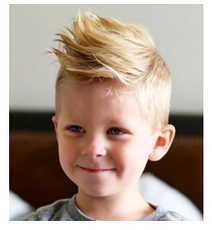




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





verb classes

Survey of **32** experimental studies on children's production and comprehension of specific verbs

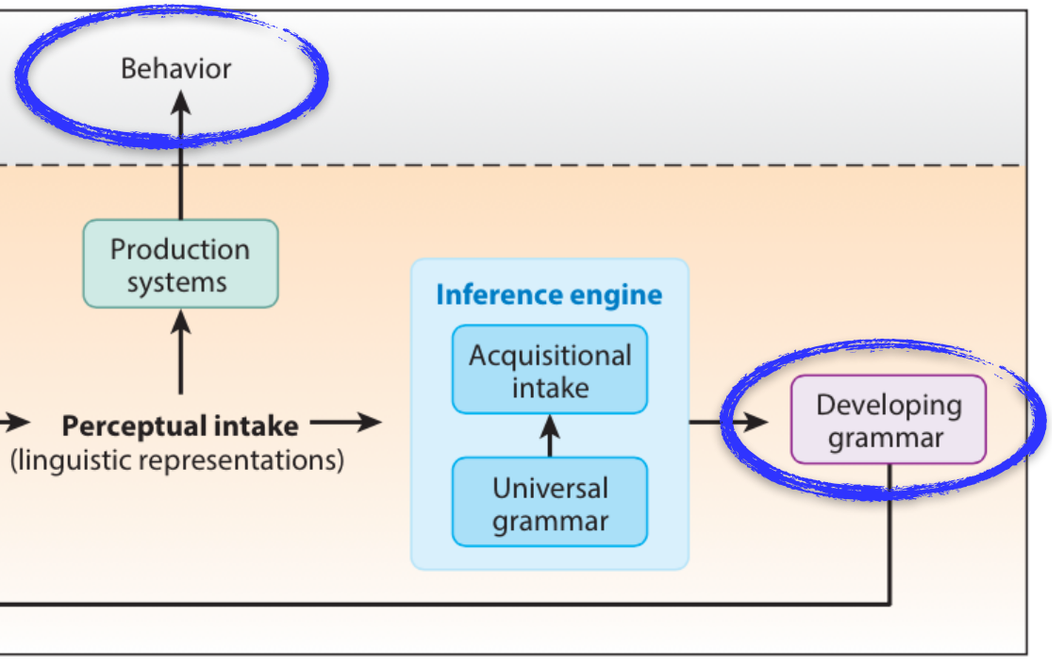
Control subject & Raising subject: Becker 2006, Becker 2007, Becker 2009, Becker 2014

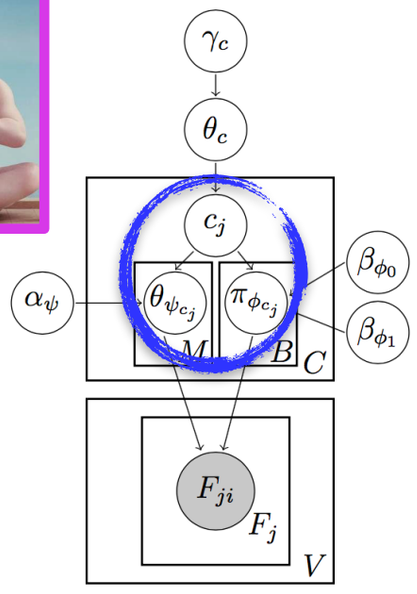
Control subject

"I ___ to leave."

doer (main)

doer (embedded)





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs

verb classes

Survey of **32** experimental studies on children's production and comprehension of specific verbs

Control subject & Raising subject: Becker 2006, Becker 2007, Becker 2009, Becker 2014

Control subject

"I ___ to leave."

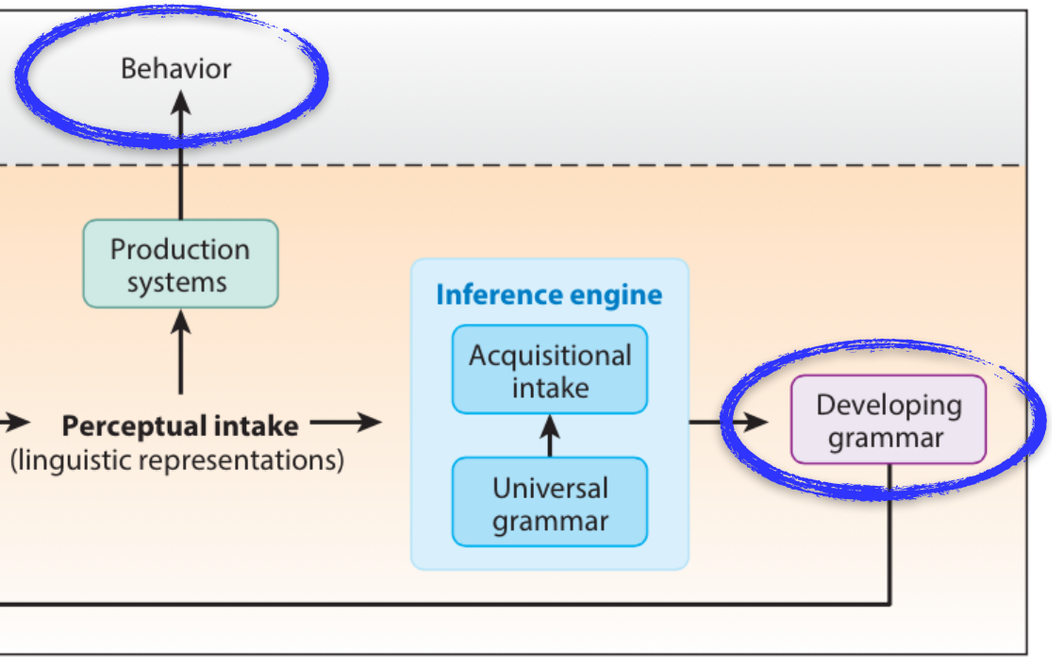
doer (main)

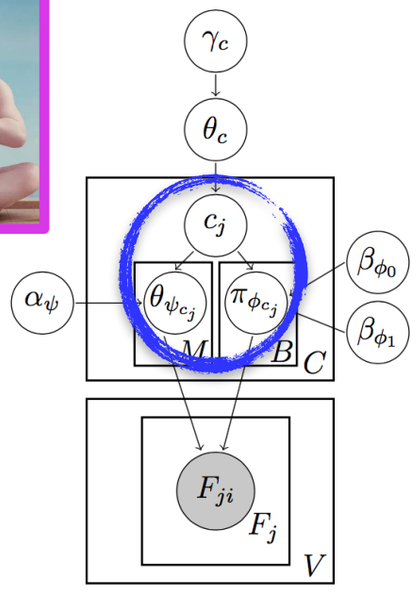
doer (embedded)

4yrs

5yrs

+= try, want





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs

verb classes

Survey of **32** experimental studies on children's production and comprehension of specific verbs

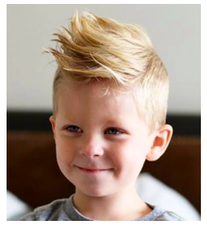
Control subject & Raising subject: Becker 2006, Becker 2007, Becker 2009, Becker 2014

Raising subject

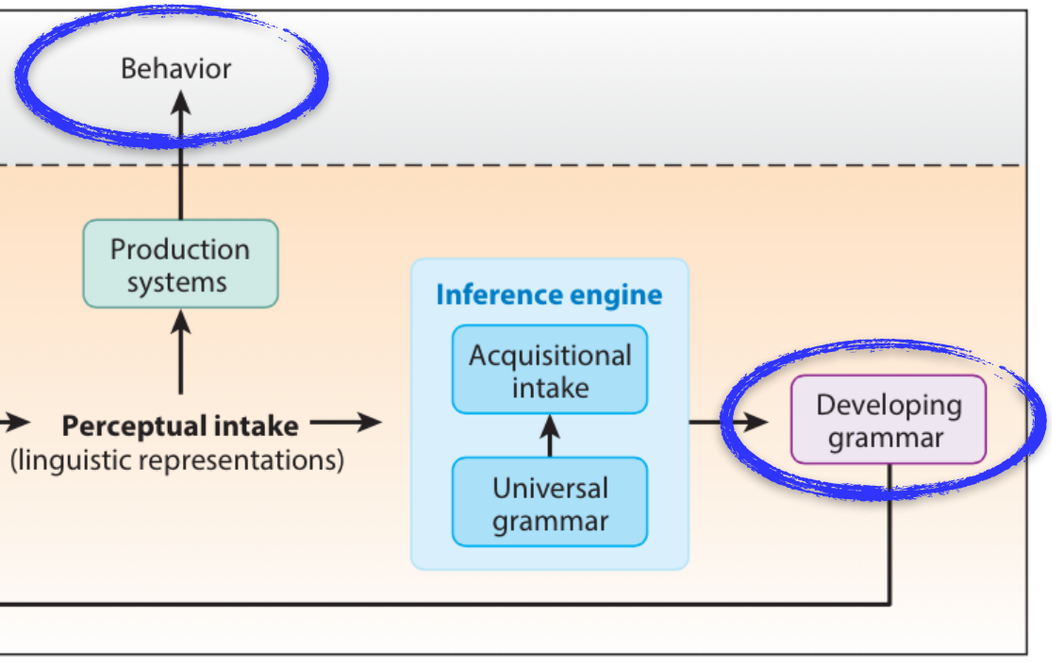
"I ___ to leave."
doer (embedded)

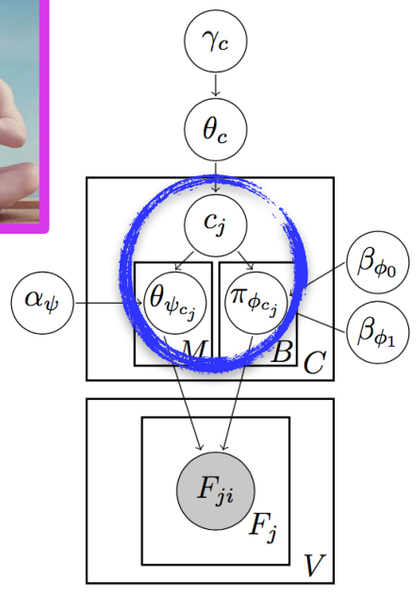
4yrs

5yrs



+= seem

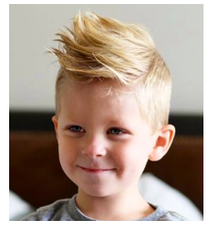




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





verb classes

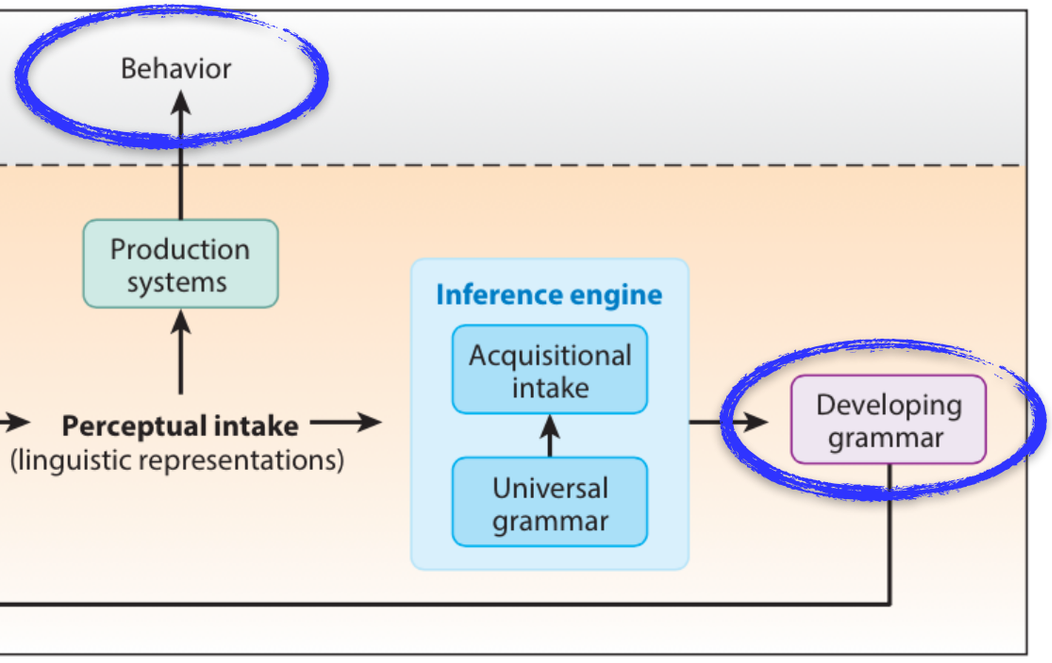
Survey of **32** experimental studies on children's production and comprehension of specific verbs

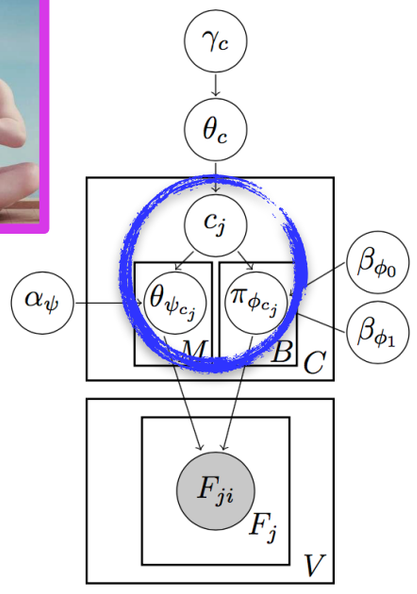
Subject-experiencer and Object-experiencer psych verbs: Hartshorne et al. 2015

Subject-experiencer

"Jack ___ Lily."

Experiencer





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs

verb classes

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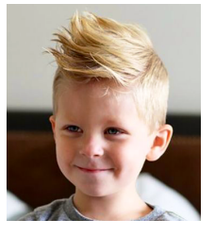
Subject-experiencer

"Jack ___ Lily."

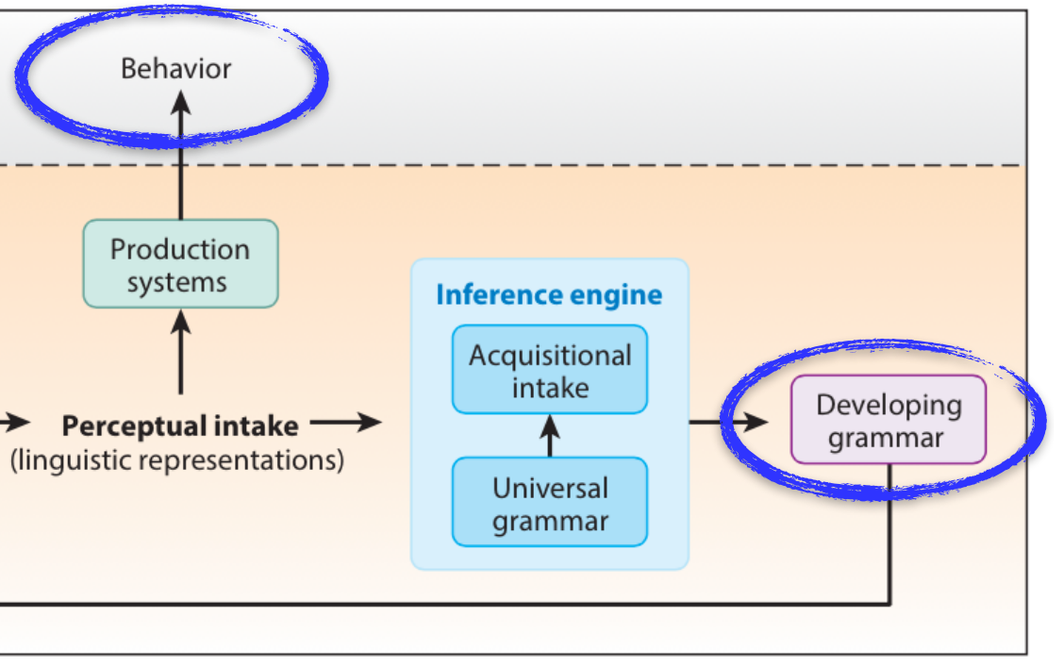
Experiencer

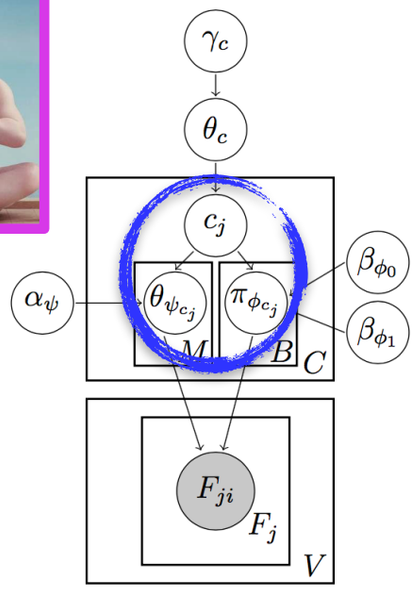
4yrs

5yrs



+= like, love





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs

verb classes

Survey of **32** experimental studies on children's production and comprehension of specific verbs

Subject-experiencer and Object-experiencer psych verbs: Hartshorne et al. 2015

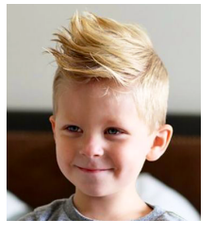
Object-experiencer

"Jack ___ Lily."

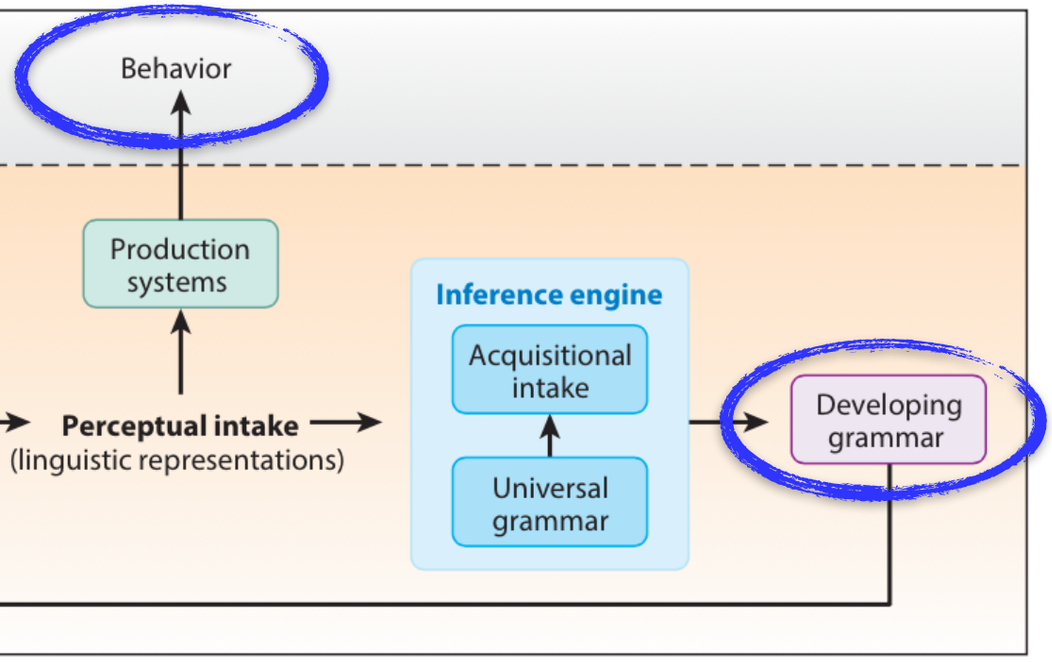
Experiencer

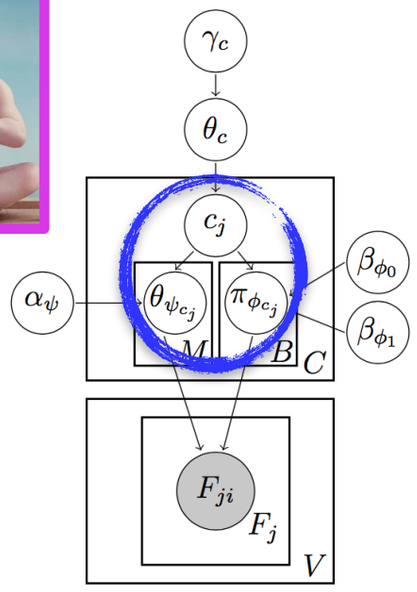
4yrs

5yrs



+= frighten, scare, surprise

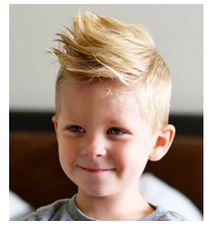




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





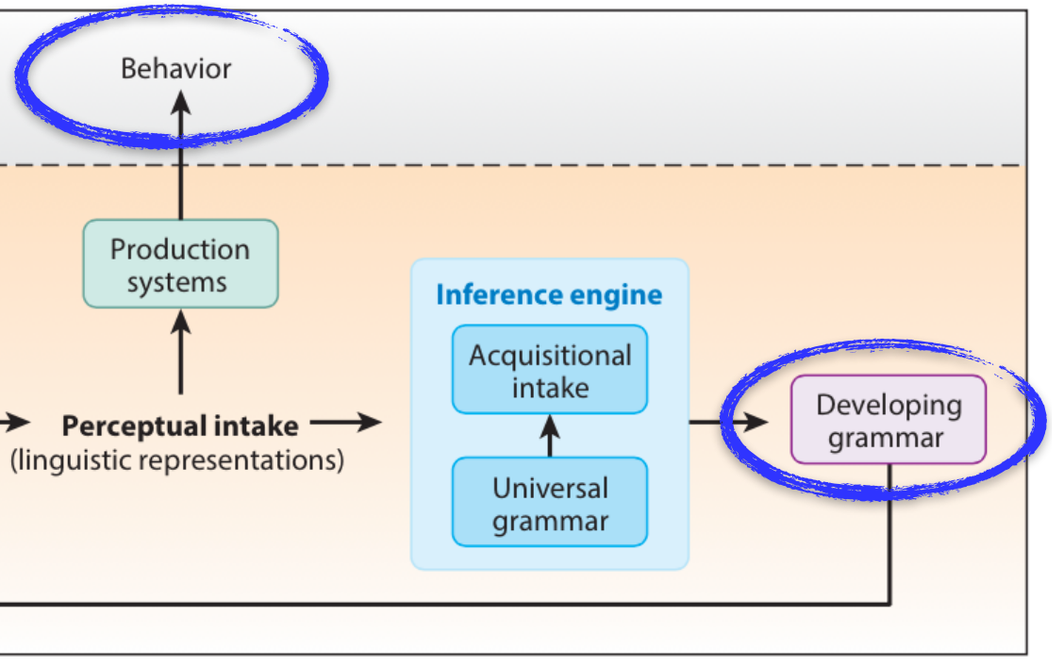
verb classes

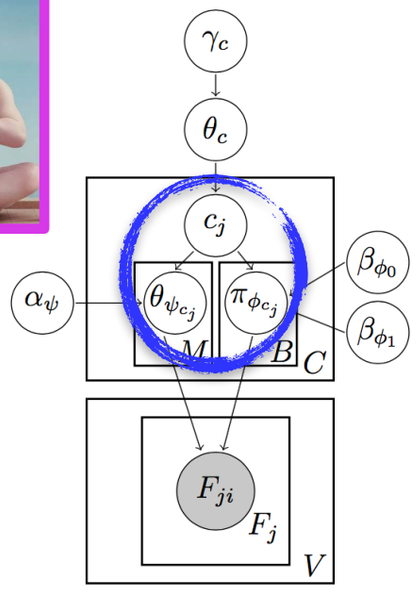
Survey of **32** experimental studies on children's production and comprehension of specific verbs

Complement-taking verbs [non-finite *to*, *that, whether/if*]: Bloom et al. 1984, Bloom et al. 1989, Diessel & Tomasello 2001, Papafragou et al. 2007, Kidd et al, 2006, Kidd et al. 2010

Non-finite to

"Jack ___ to go."

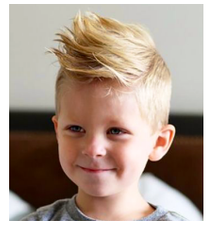




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<4yrs

<5yrs



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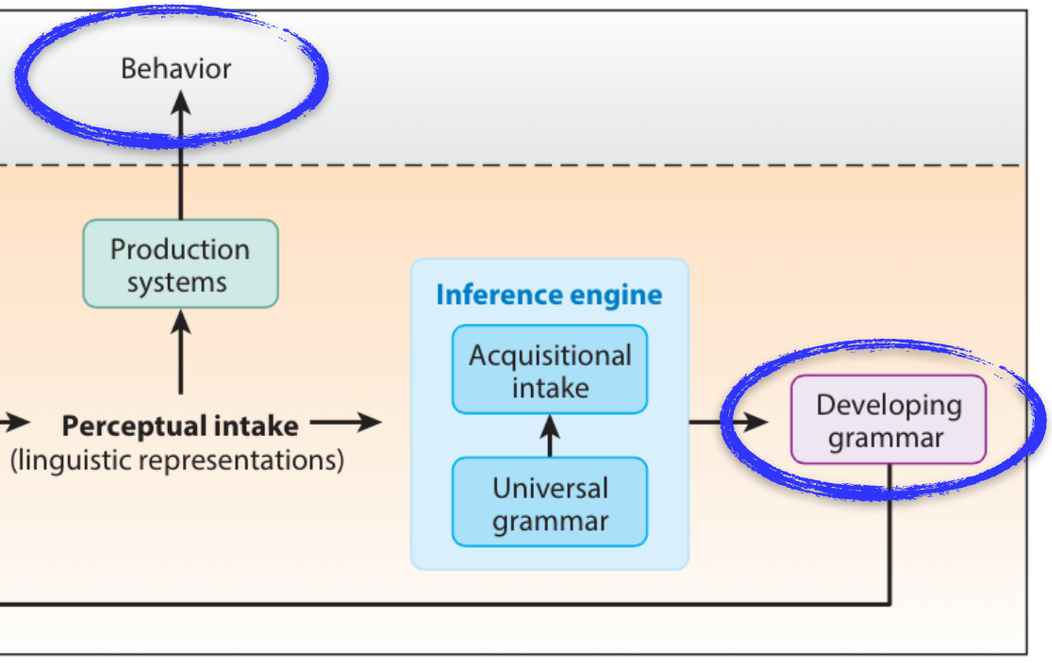
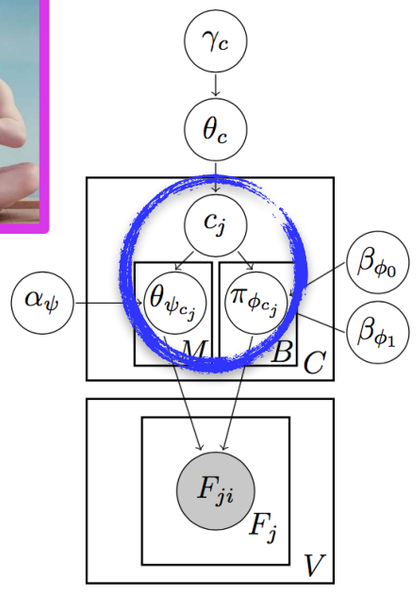
Non-finite to

"Jack ___ to go."

3yrs

+= get, start, suppose, …

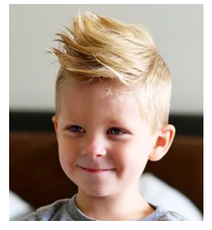




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





verb classes

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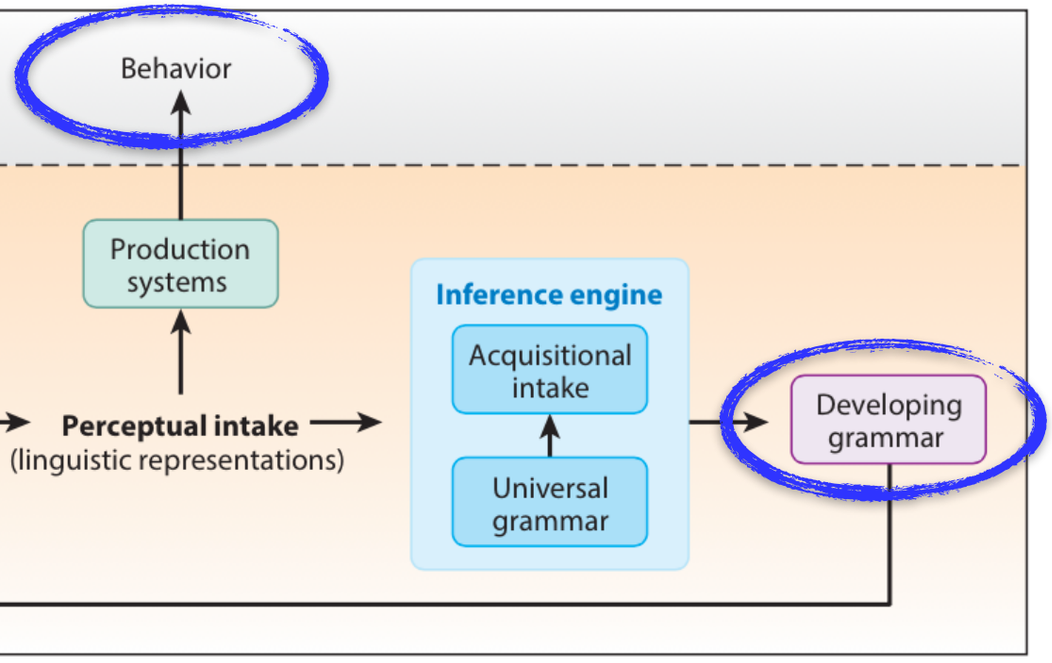
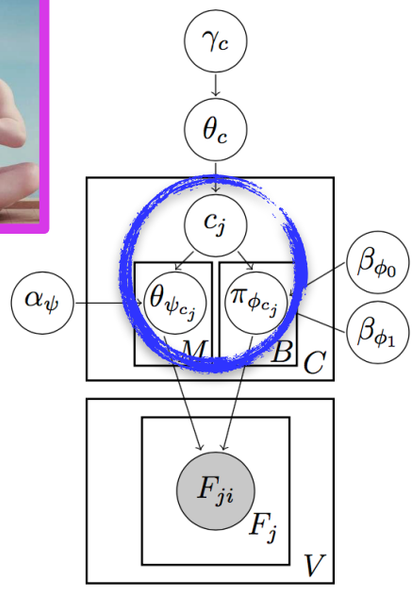
Complement-taking verbs [non-finite *to*, *that, whether/if*]: Bloom et al. 1984, Bloom et al. 1989, Diessel & Tomasello 2001, Papafragou et al. 2007, Kidd et al, 2006, Kidd et al. 2010

that

"Jack ___ that he can go."

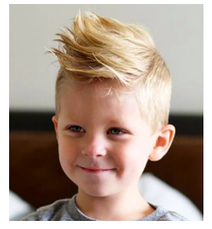




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<4yrs

<5yrs



verb classes

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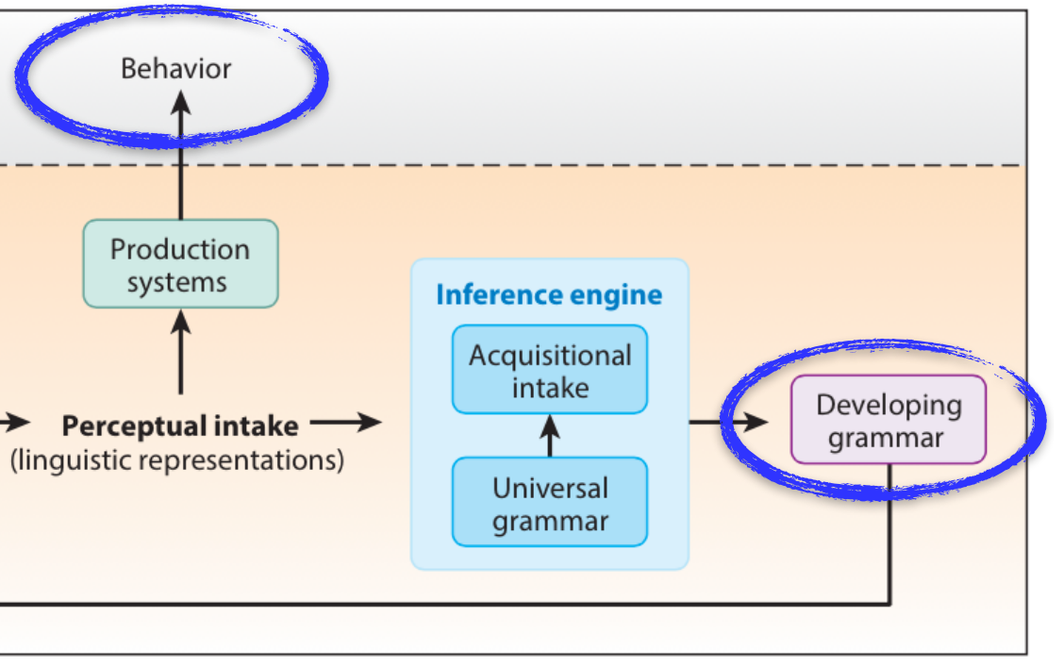
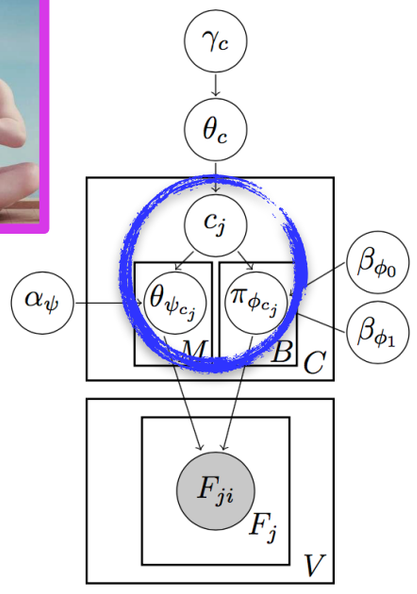
that

"Jack ___ that he can go."

3yrs

+= hope, know, say, …





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs**

verb classes

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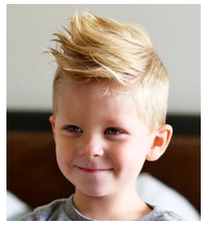
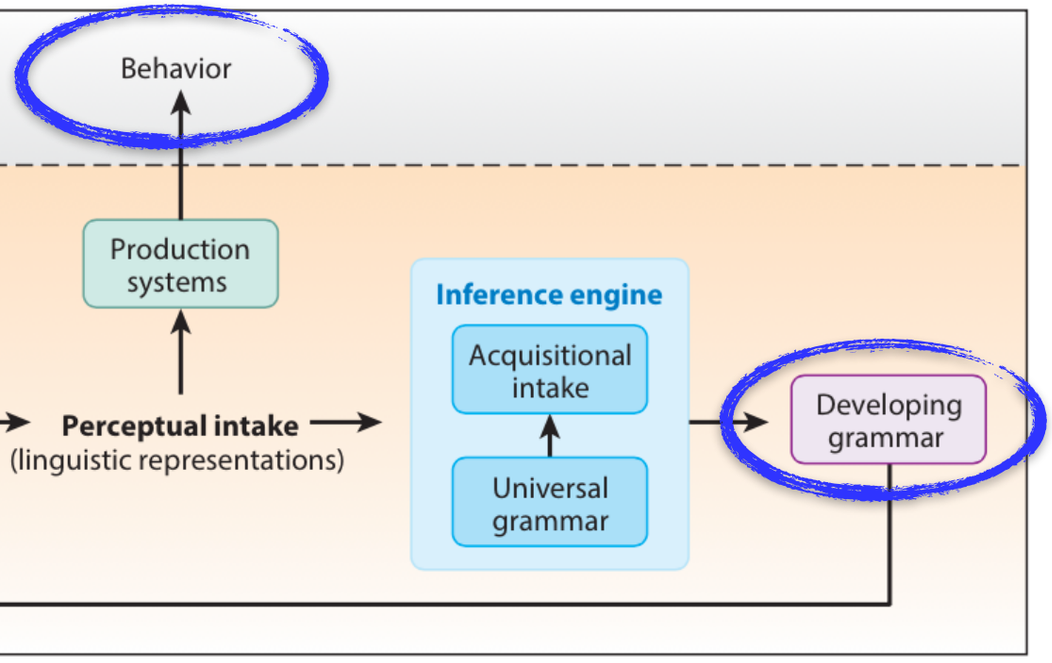
that

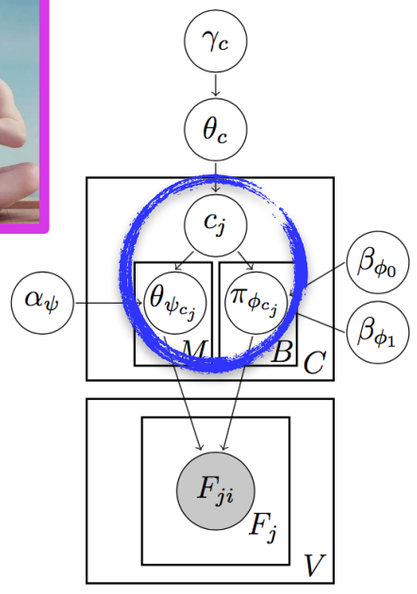
"Jack ___ that he can go."

5yrs



+= guess, hope, know, pretend, say, …

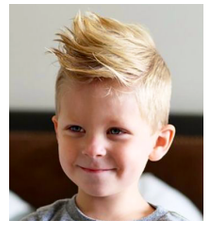




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





verb classes

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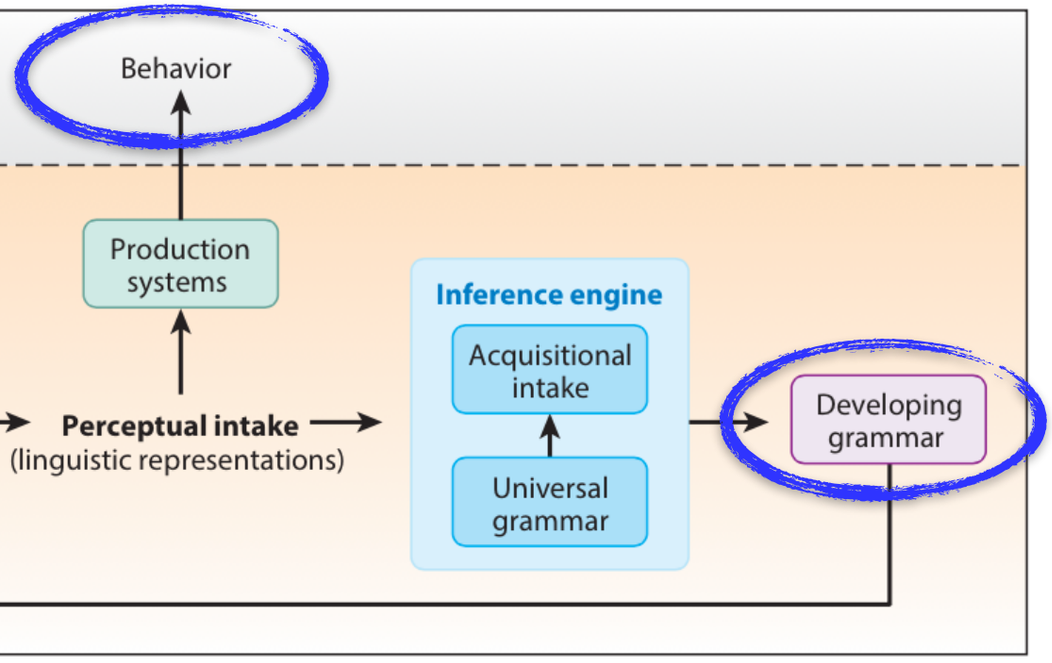
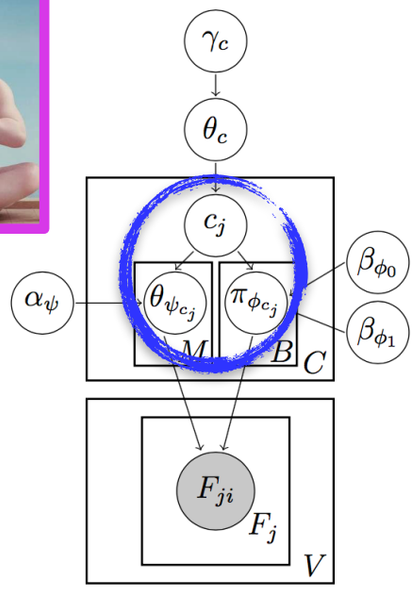
Complement-taking verbs [non-finite *to*, *that*, *whether/if*]: Bloom et al. 1984, Bloom et al. 1989, Diessel & Tomasello 2001, Papafragou et al. 2007, Kidd et al, 2006, Kidd et al. 2010

whether/if

"Jack ___ whether/if he can go."





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verb classes

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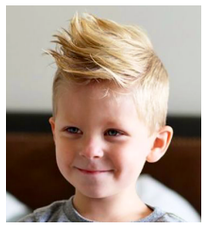
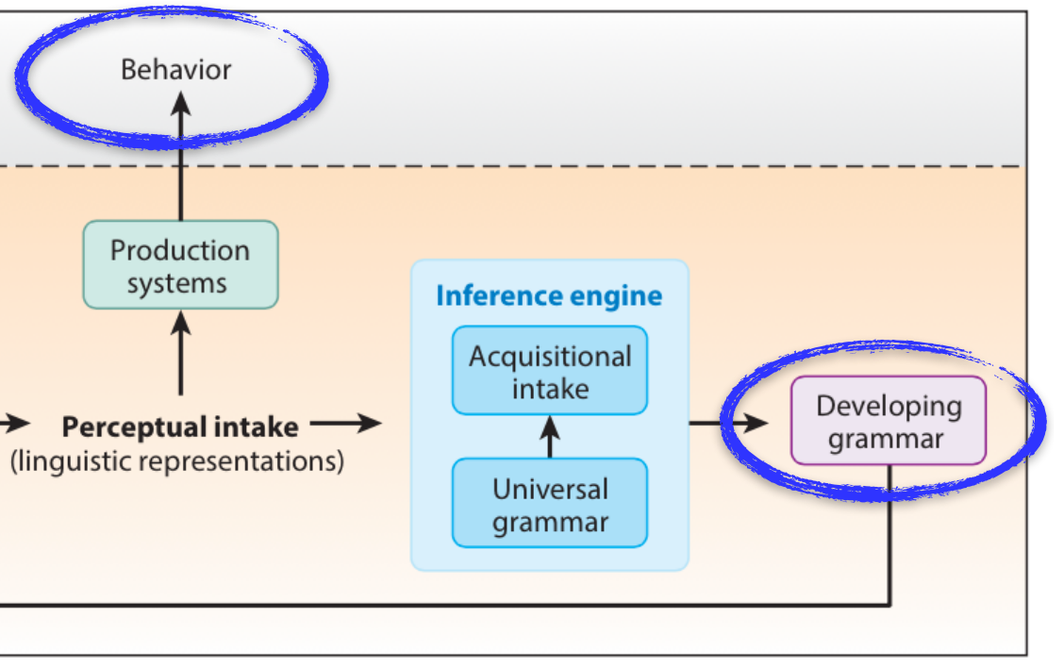
whether/if

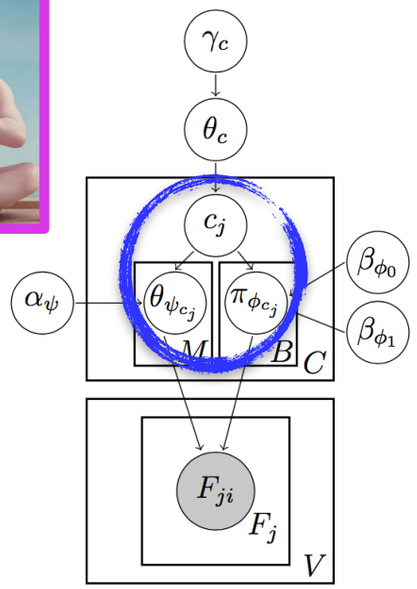
"Jack ___ whether/if he can go."

5yrs



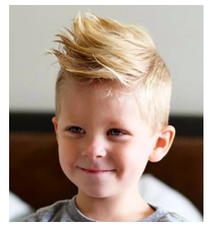
+= ask, care, know, see, …



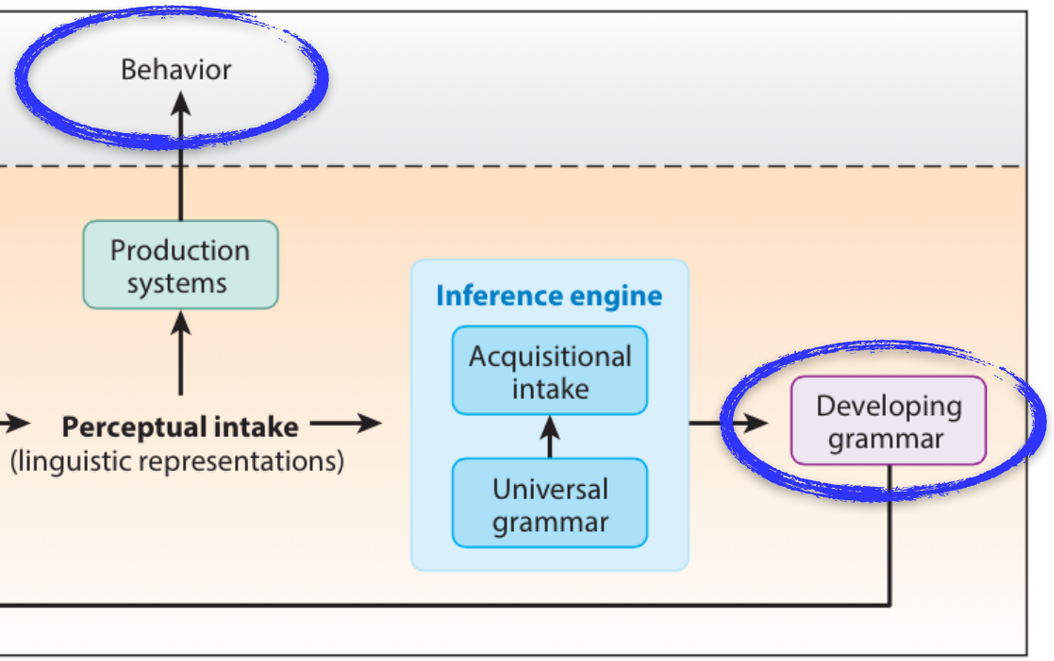


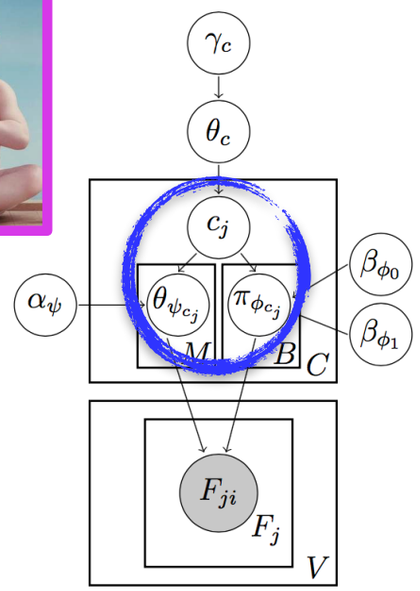
Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



These verb behaviors yield a number of **verb classes** at each age

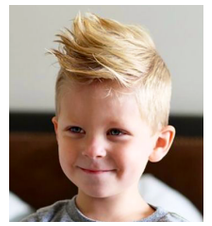




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<4yrs

<5yrs



These verb behaviors yield a number of **verb classes** at each age

<3yrs

Example classes

[+passive]: carry, chase, crash, drop, eat, hit, hold, hurt, jump, kick, kiss, knock, lick, punch, push, scratch, shake, turn, wash, watch

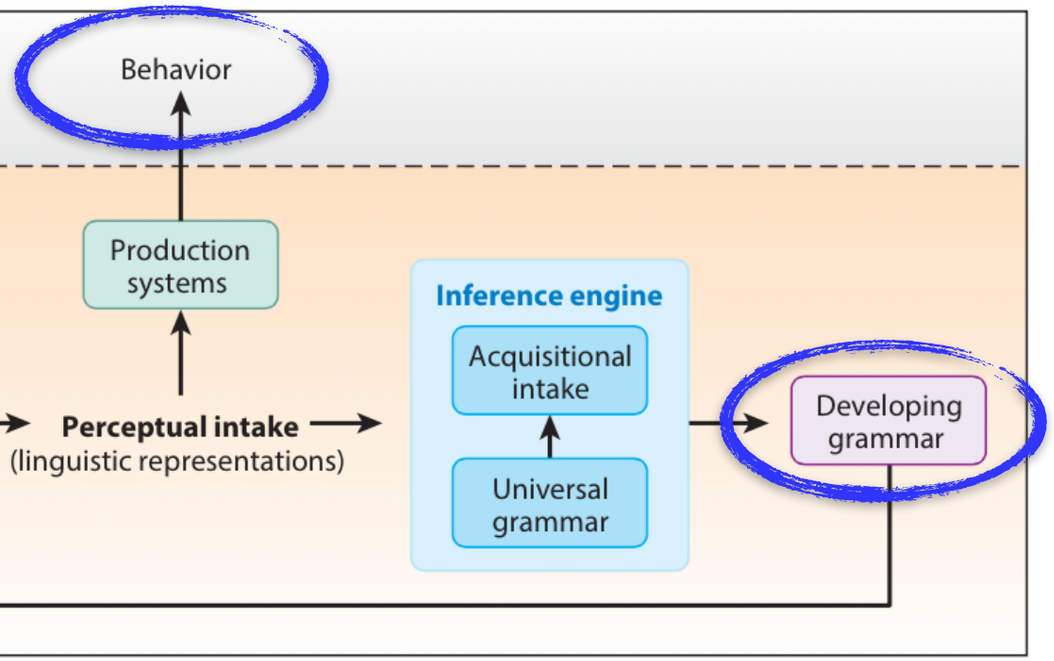
[-passive]: believe, remember

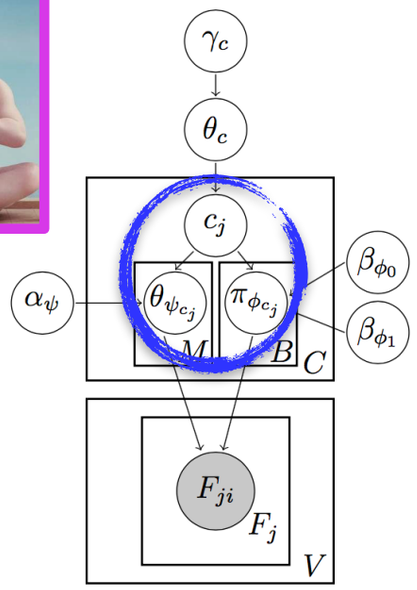
[+non-finite *to*]: ask, have, need, start, suppose, teach, try, use, want

[+*that*-comp]: bet, hope, think, wish

[+passive, +non-finite *to*]: like

[+passive, +*that*-comp]: see

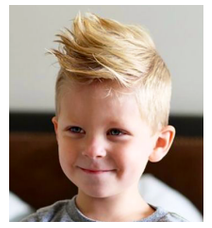




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs

<5yrs



These verb behaviors yield a number of **verb classes** at each age

<4yrs

Example classes

[+passive]: bite, bump, carry, chase, crash, drop, find, hit, hold, hurt, jump, kick, kill, kiss, knock, lick, pull, punch, push, ride, scratch, shake, shoot, turn, wash, watch

[-passive]: believe, remember

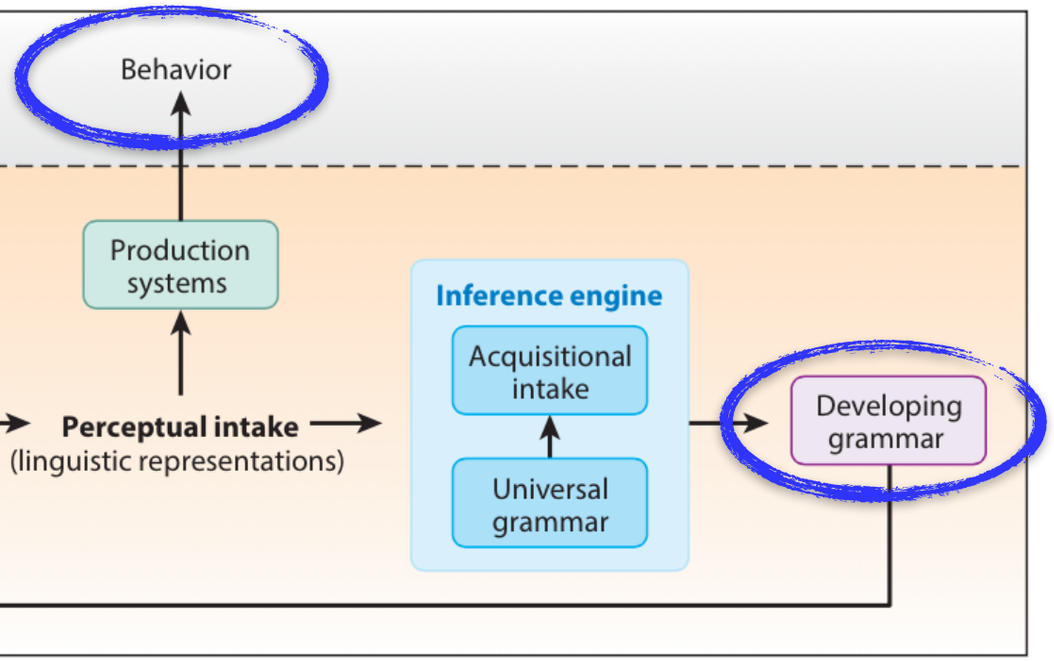
[+*that*-comp]: bet, hope, think, wish

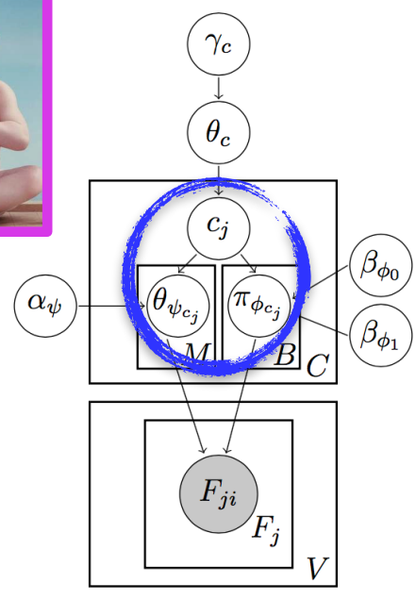
[+non-finite *to,* +raising-obj]: need

[+non-finite *to,* +raising-obj, +control-subj]: want

[+passive, +non-finite *to,* +psych-subj]: like

[+passive, +*that*-comp]: see





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs

<4yrs

These verb behaviors yield a number of **verb classes** at each age

<5yrs

Example classes

[+passive]: bite, bump, carry, chase, crash, drop, find, hit, hold, hurt, jump, kick, kill, kiss, knock, lick pull, push, ride, scratch, shake, shoot, turn, wash, watch

[-passive]: believe, remember

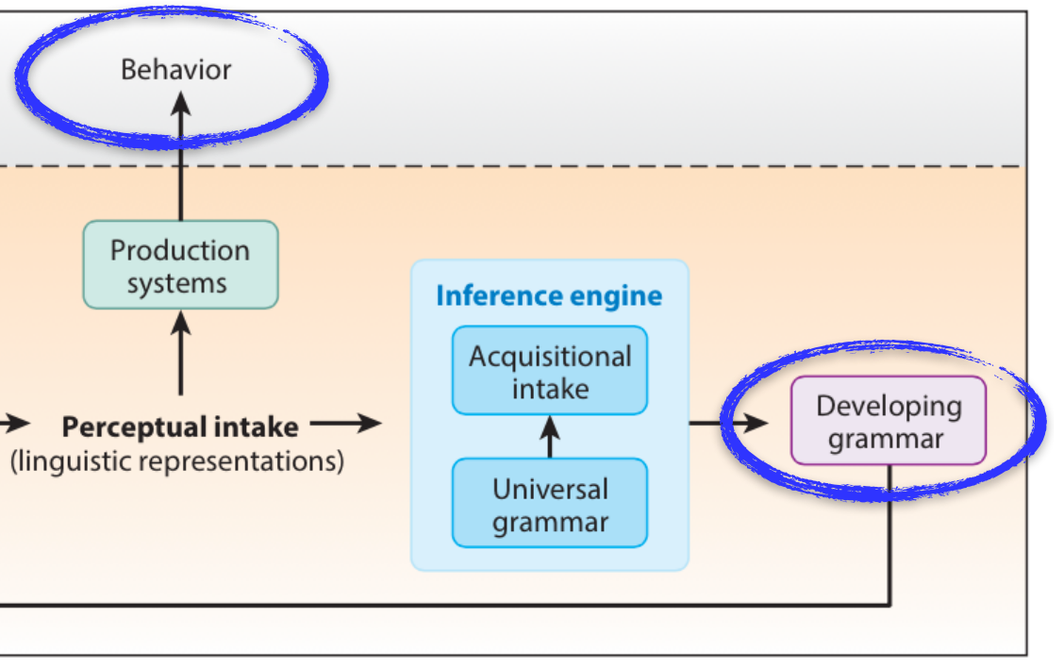
[+*that*-comp]: bet, dream, guess, hope, lie, pretend, think, wish

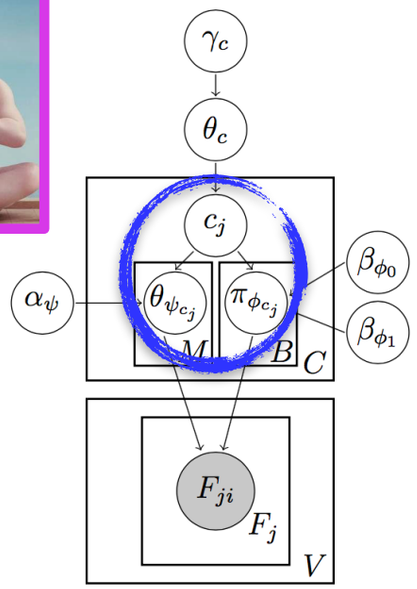
[+non-finite *to,* +raising-obj]: need

[+non-finite *to,* +raising-obj, +control-subj]: want

[+passive, +non-finite *to,* +psych-subj]: like

[+passive, +*that*-comp, +*whether/if*-comp]: see





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

These verb behaviors yield a number of **verb classes** at each age

<3yrs

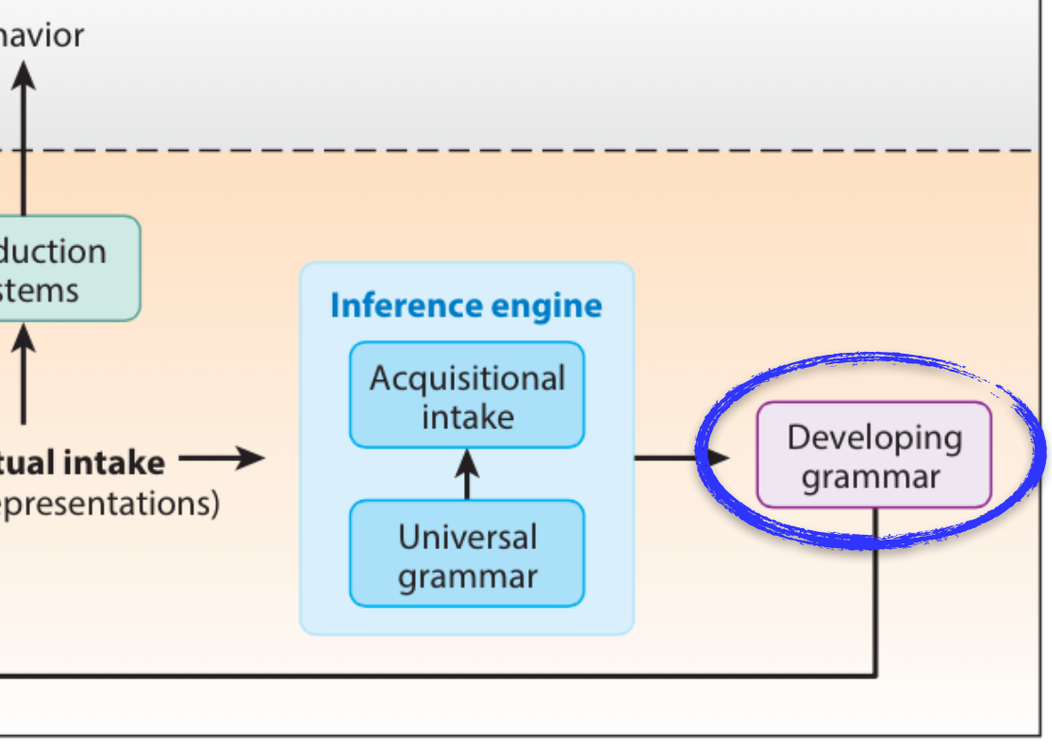
15 classes of 60 verbs total

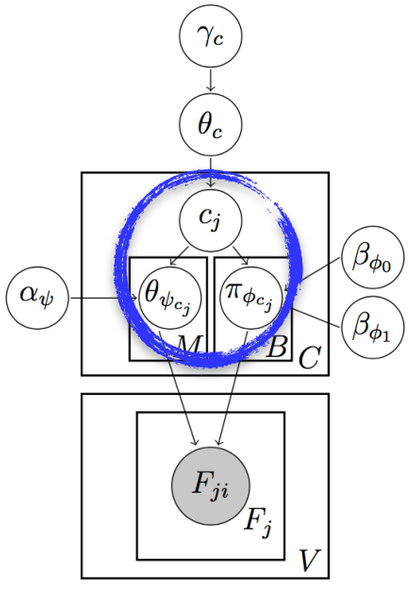
<4yrs

23 classes of 76 verbs total

<5yrs

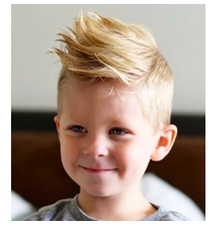
24 classes of 82 verbs total





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

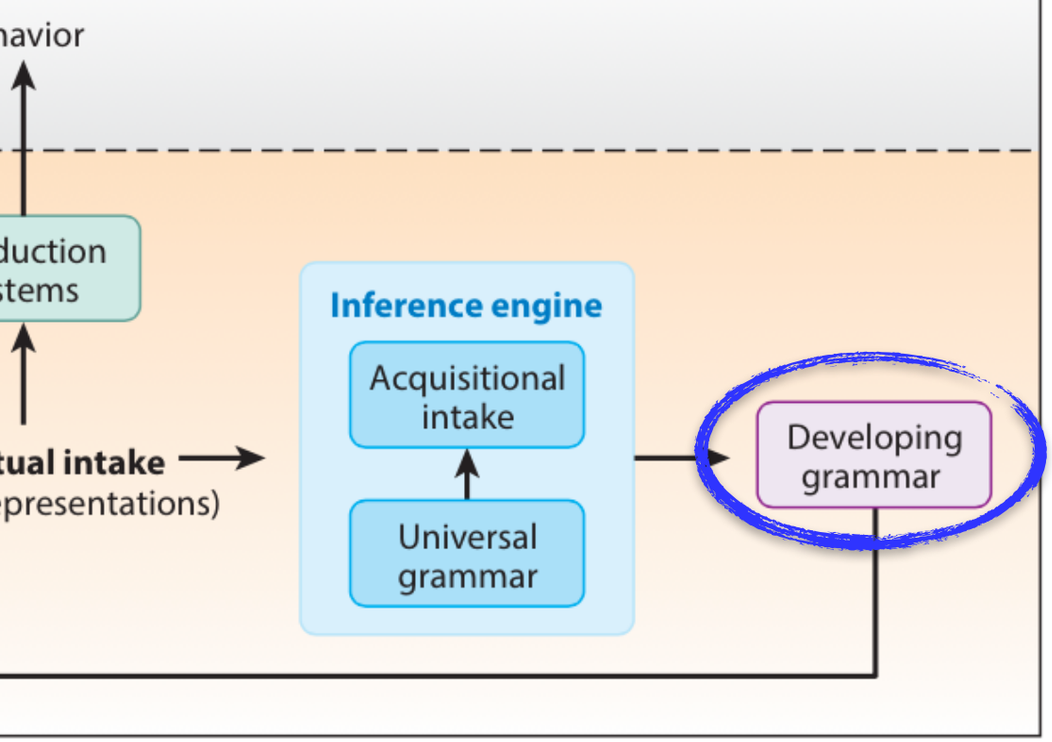
<3yrs **<4yrs** **<5yrs**

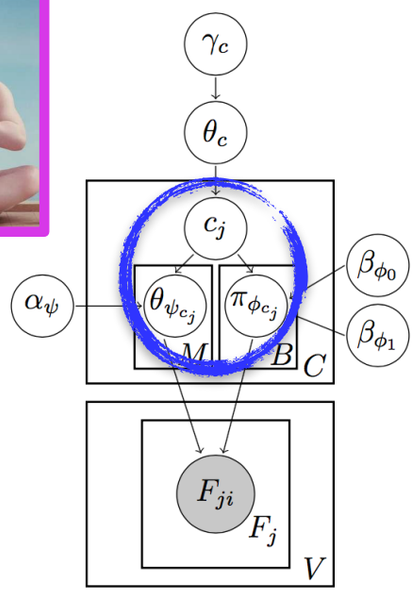


15 classes **23 classes** **24 classes**

Evaluation:

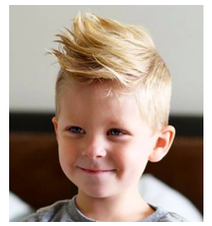
How well did the modeled learner do at finding these verb classes?





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**

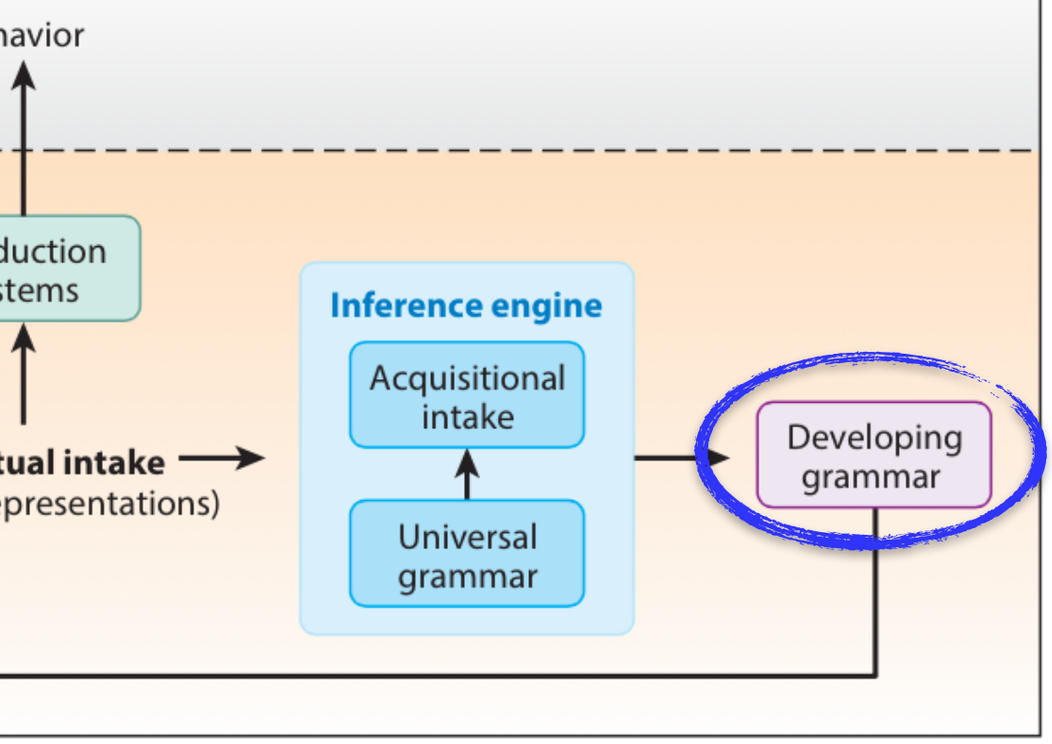


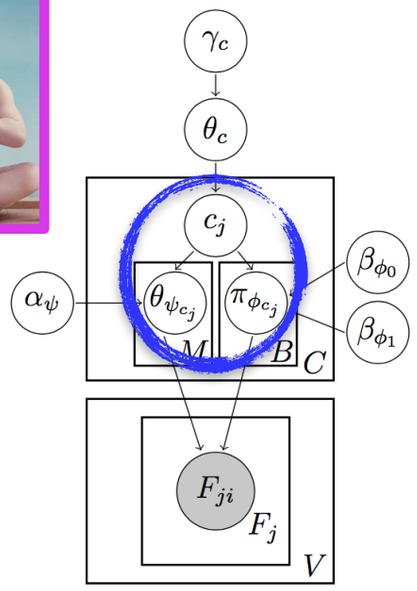
15 classes **23 classes** **24 classes**

Implementation:
Random Index

0.0 <= RI <= 1.0

Intuition: Get credit for putting things together that belong together and keeping things apart that don't belong together.

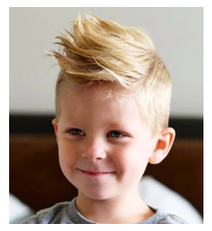




Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





15 classes **23 classes** **24 classes**

Implementation:

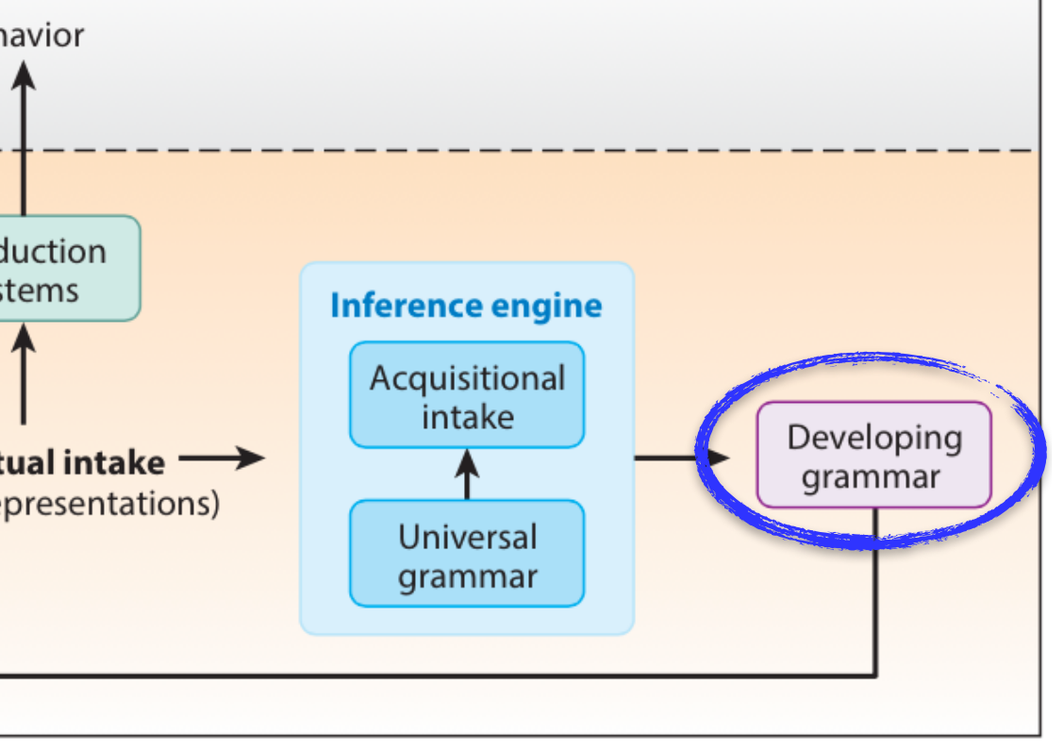
Random Index

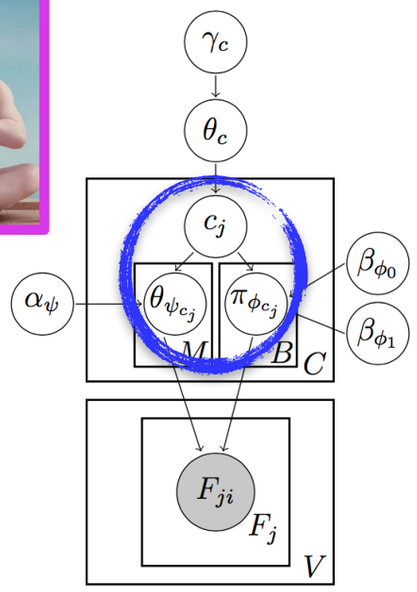

0.0 <= RI <= 1.0

For each pair of verbs in the inferred classes: $verb_i$ $verb_j$

		Inferred Class	
		Same class	Different class
True	Same class	True Positive	False Negative
	Different class	False Positive	True Negative

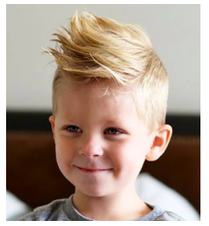
Intuition: Get credit for putting things together that belong together and keeping things apart that don't belong together.





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



15 classes **23 classes** **24 classes**

Implementation:

Random Index

0.0 <= RI <= 1.0

$$\frac{\text{True Positives} + \text{True Negatives}}{\text{True Positives} + \text{True Negatives} + \text{False Positives} + \text{False Negatives}}$$

For each pair of verbs in the inferred classes: verb_i verb_j

		Inferred Class	
		Same class	Different class
True	Same class	True Positive	False Negative
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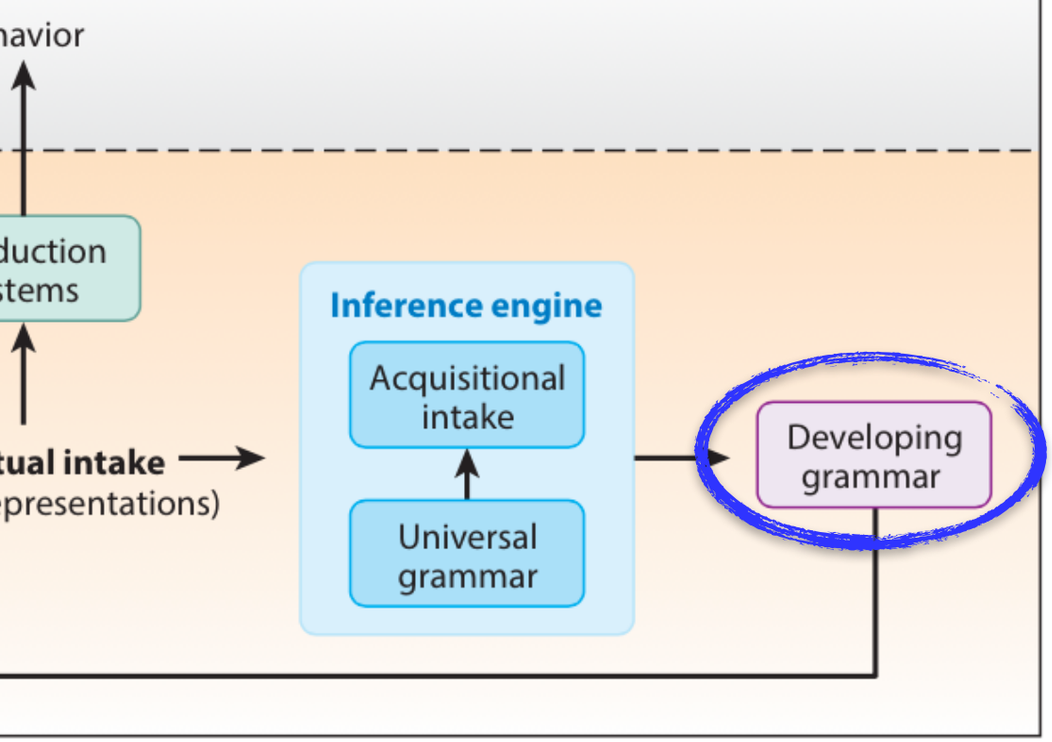
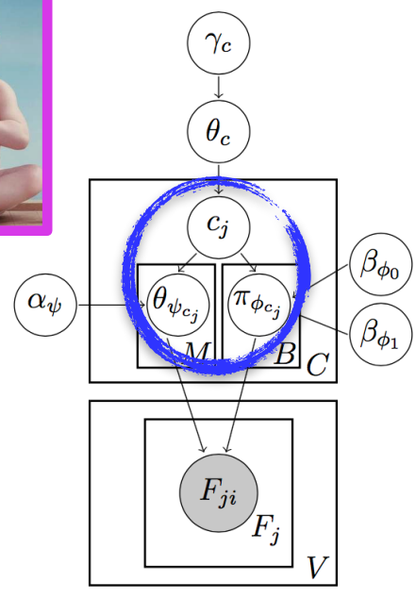
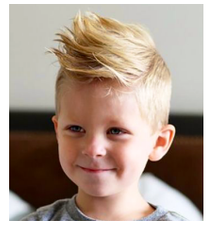
Intuition: Get credit for putting things together that belong together and keeping things apart that don't belong together.





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



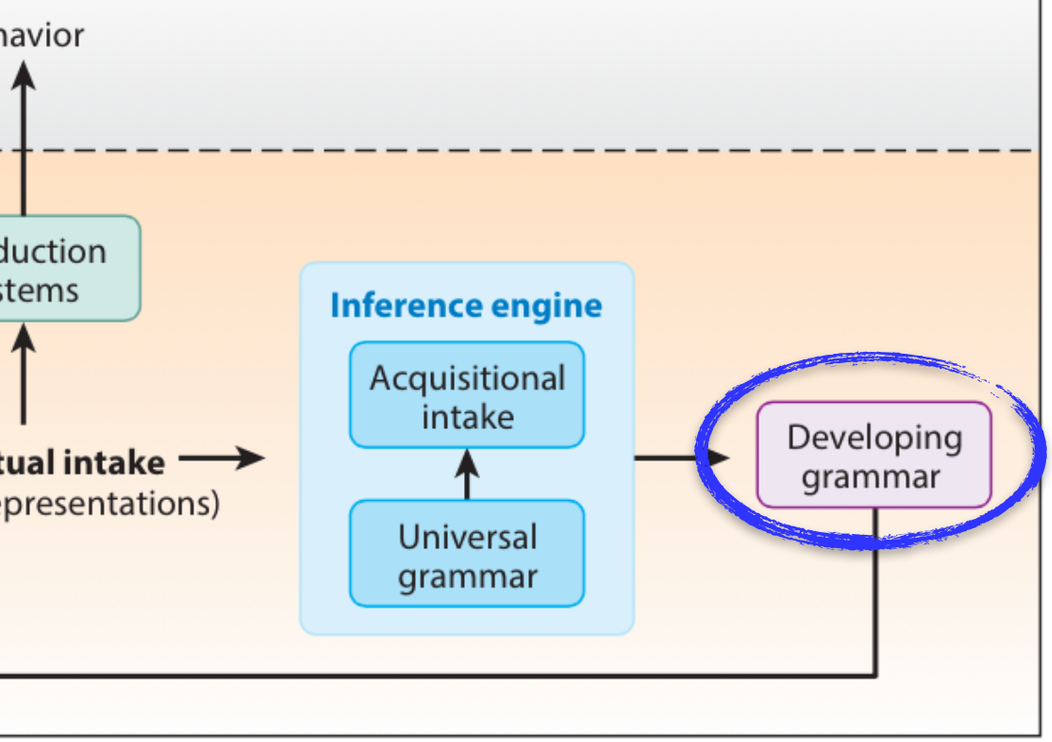
15 classes **23 classes** **24 classes**

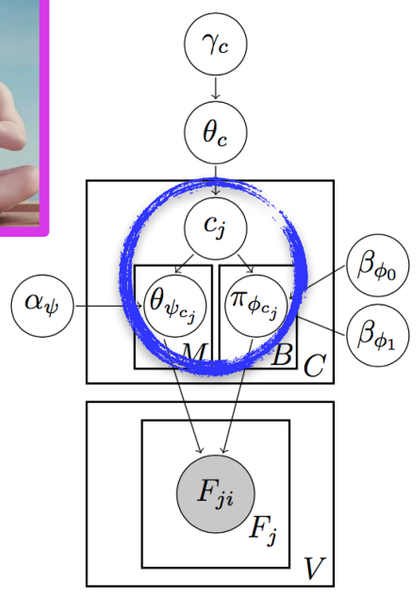
Implementation:
Random Index

0.0 <= RI <= 1.0

Intuition: Get credit for putting things together that belong together and keeping things apart that don't belong together.

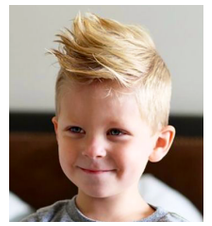
But how do we know we're doing better than chance?





Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



15 classes **23 classes** **24 classes**

Implementation:

Adjusted Random Index

-1.0 <= ARI <= 1.0

Compared against the expected value of the Random Index:

1.0 = perfect classification

>0 = better than chance

0 = chance performance

<0 = worse than chance

-1.0 = perfectly awful classification

Today's plan

Verb classes

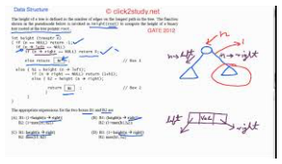
done-to

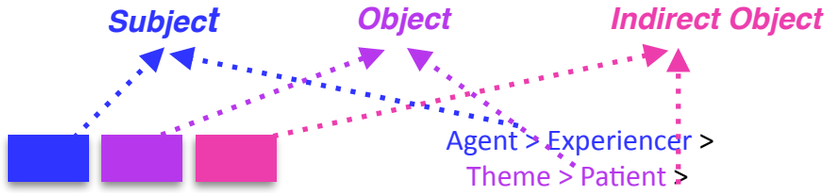
The ice melted.

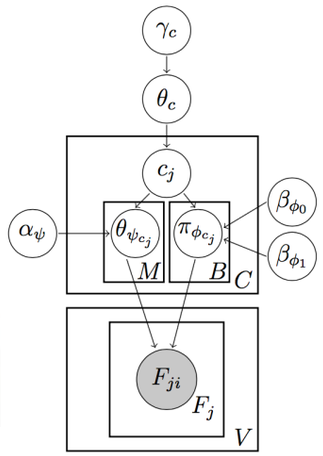
The penguin climbed.

doer

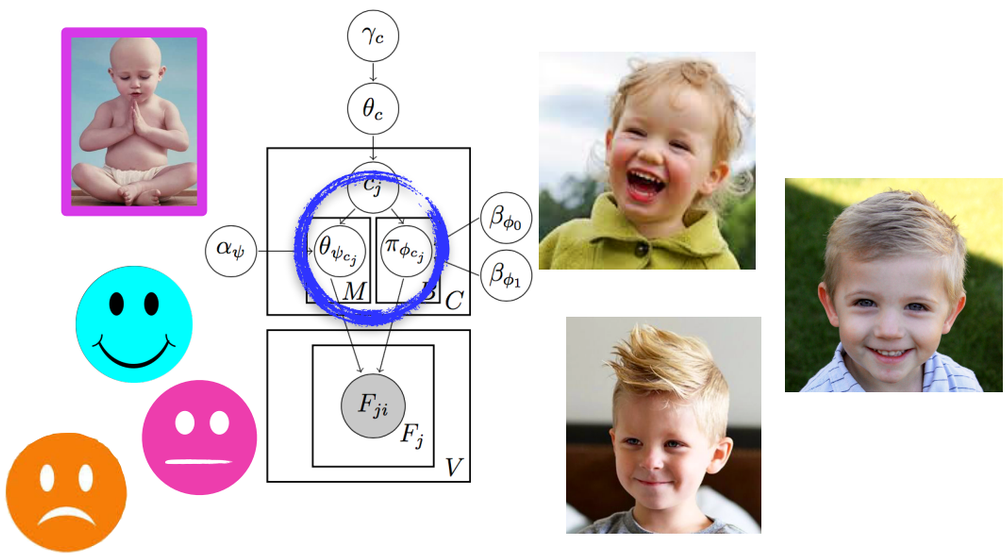
Computational modeling





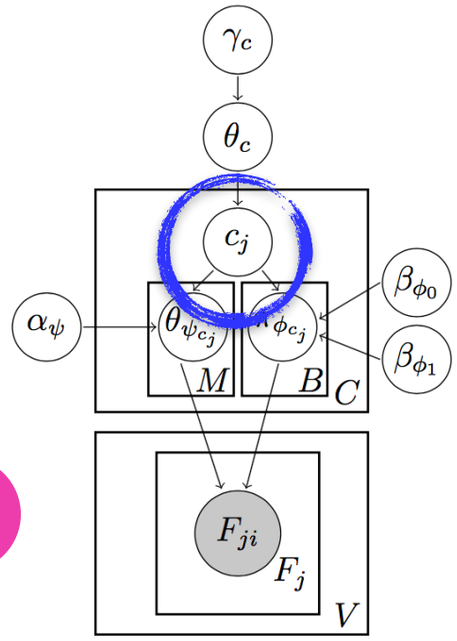


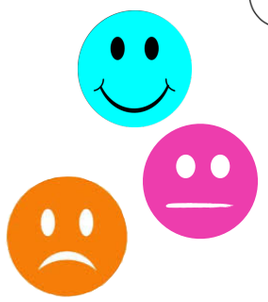
Results & implications

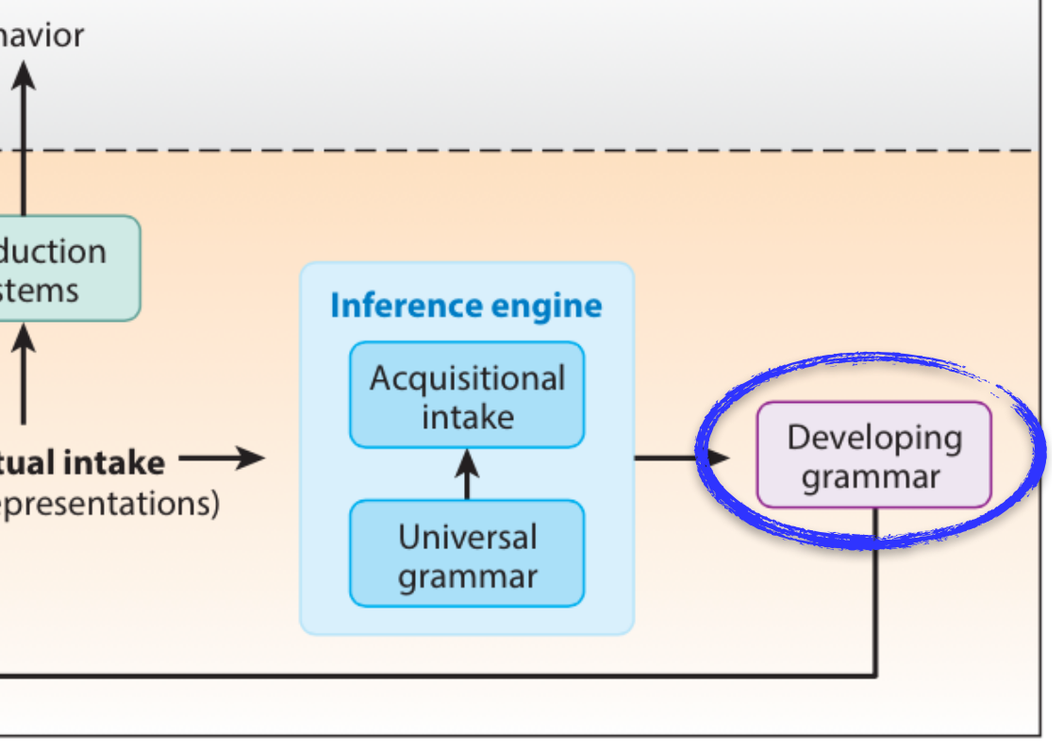


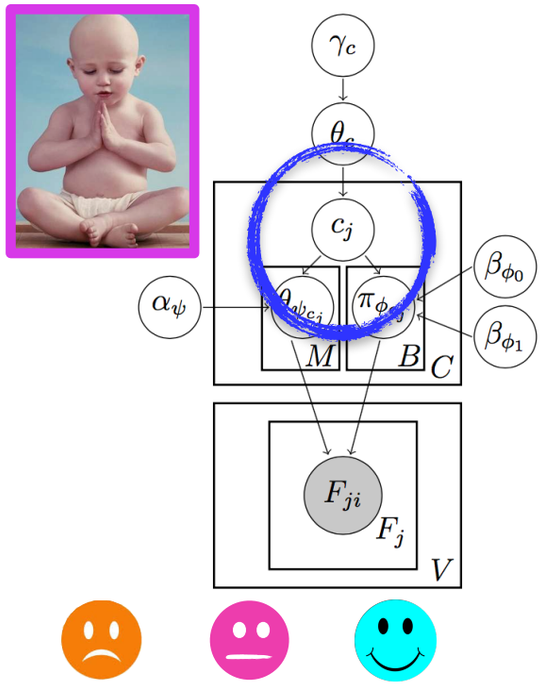
Today's plan

Results & implications





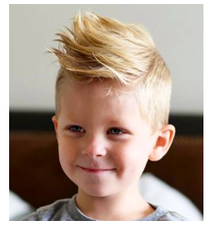




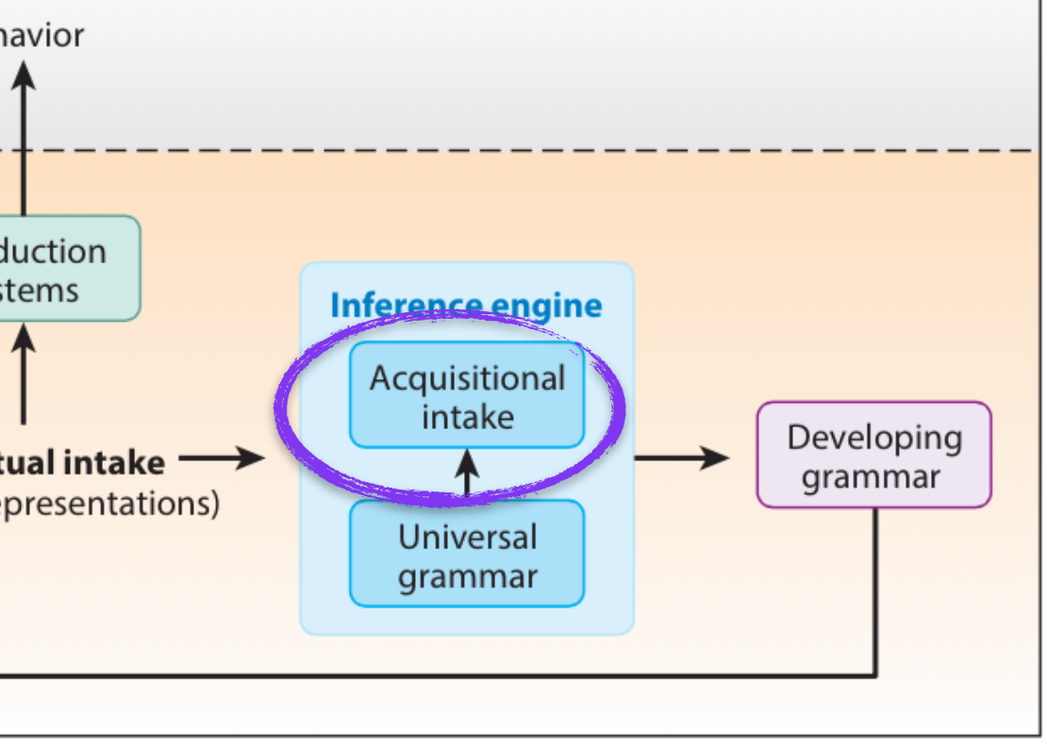
-1.0 <= ARI <= 1.0

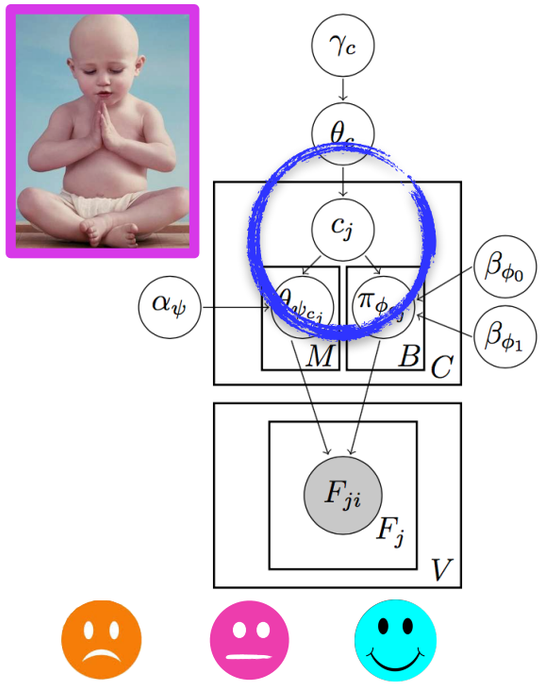
Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



15 classes **23 classes** **24 classes**



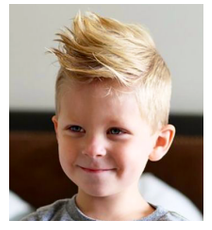


-1.0 <= ARI <= 1.0

Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



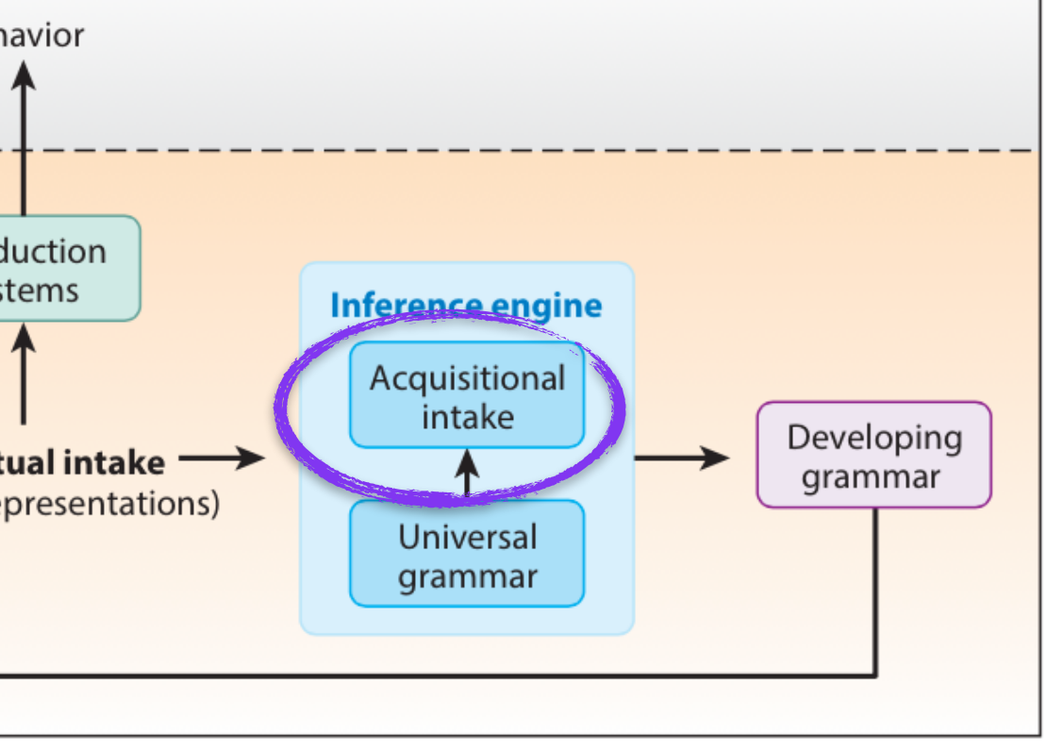


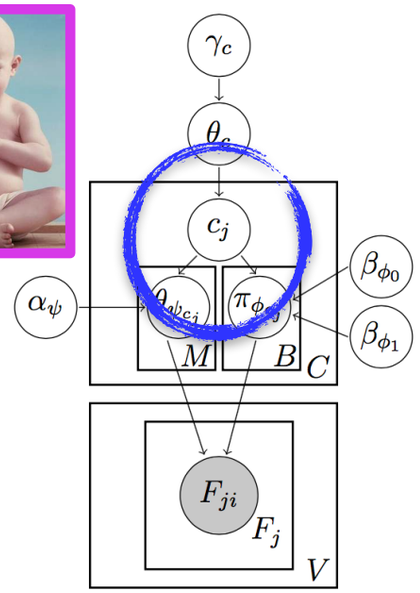
15 classes **23 classes** **24 classes**

Animacy

+animate
The penguin tried to climb.

-animate
The ice seemed to melt.



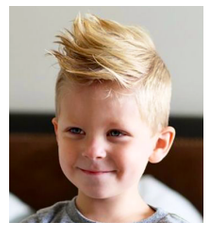


-1.0 <= ARI <= 1.0

Animacy

Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



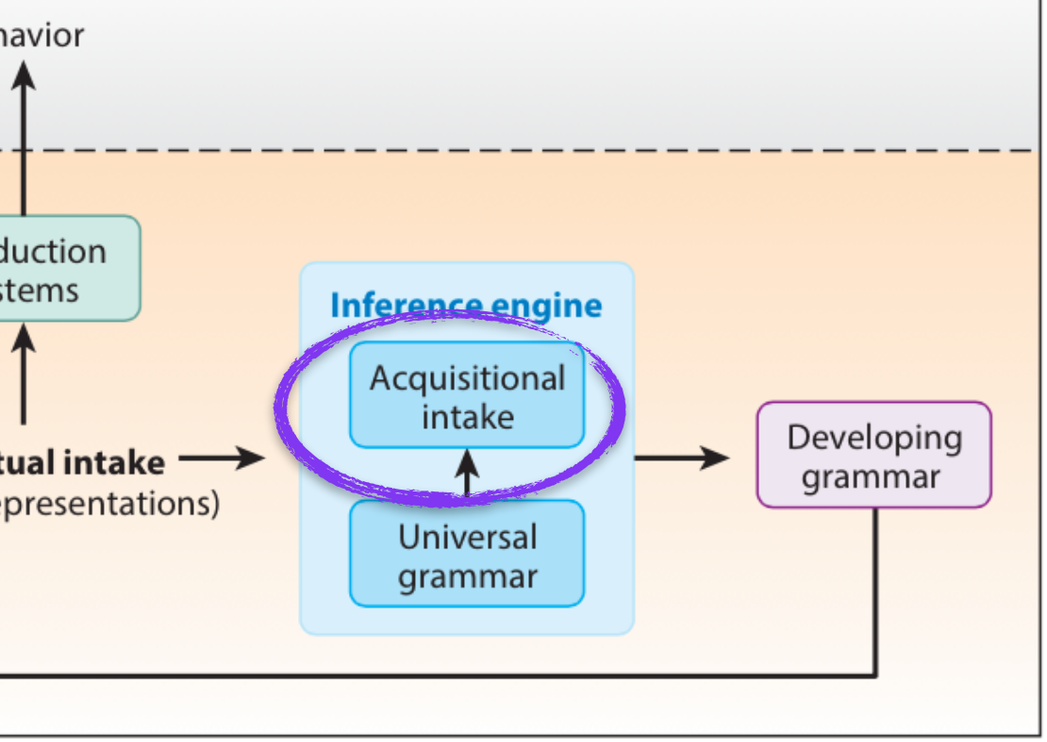
15 classes **23 classes** **24 classes**

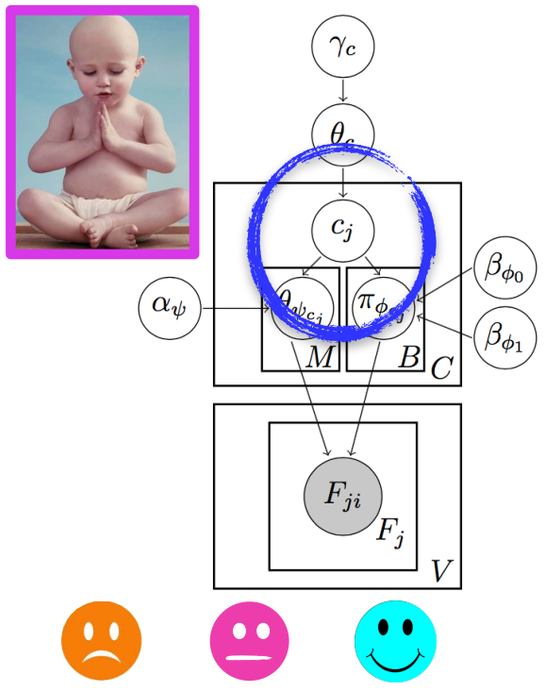
Syntactic frame

The ice seemed to melt.

NP ___ $S_{nonfinite}$ -surfmorph

NP ___**+past** $S_{nonfinite}$ +surfmorph





-1.0 <= ARI <= 1.0

Animacy

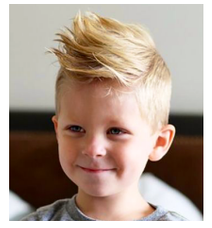
Syntactic frame

+surfmorph

-surfmorph

Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**



15 classes **23 classes** **24 classes**

Thematic roles and how to use them

UTAH

Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)

rUTAH

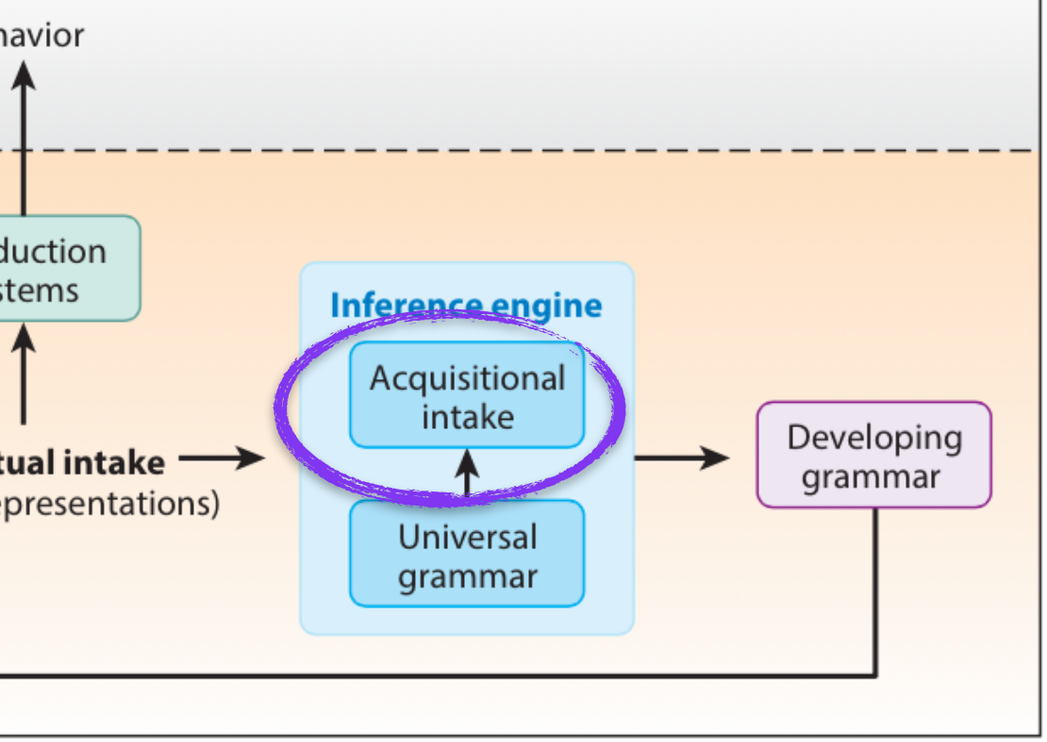
-expmap

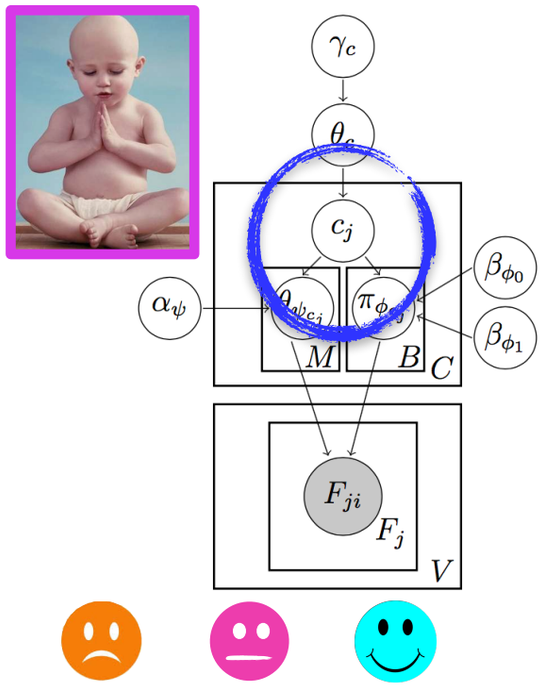
Subject *Object* *Indirect Object*

+expmap

Subject *Object* *Indirect Object*

movement?



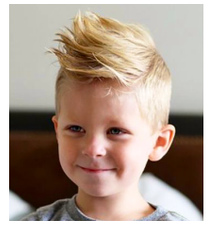


-1.0 <= ARI <= 1.0

Goal: Model the developmental trajectory from 3 to 4 to 5 years old

<3yrs **<4yrs** **<5yrs**





15 classes **23 classes** **24 classes**

Animacy

Syntactic frame

+surfmorph -surfmorph

Thematic roles and how to use them

UTAH rUTAH UTAH rUTAH

+expmap *-expmap* *+expmap* *-expmap* *+expmap* *-expmap* *+expmap* *-expmap*

Developing grammar

Animacy

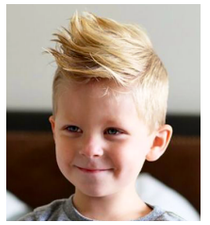
Syntactic frame

-1.0 <= ARI <= 1.0

<4yrs

23 classes

<5yrs



24 classes

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH

+expmap *-expmap*

rUTAH

+expmap *-expmap*

UTAH

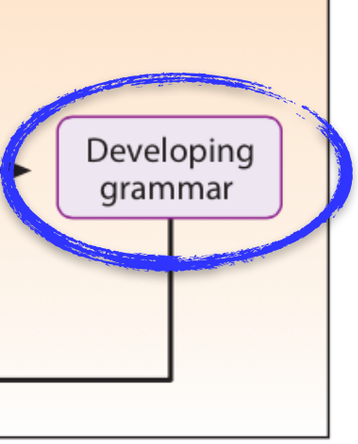
+expmap *-expmap*

rUTAH

+expmap *-expmap*

3yrs

15 classes



Animacy

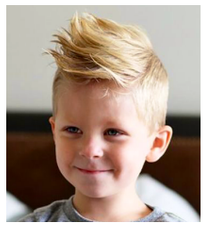
Syntactic frame

-1.0 <= ARI <= 1.0

<4yrs

23 classes

<5yrs



24 classes

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH

+expmap *-expmap*

rUTAH

+expmap *-expmap*

UTAH

+expmap *-expmap*

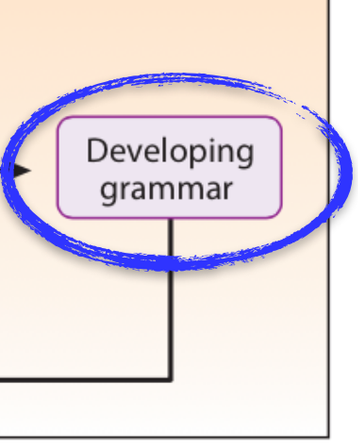
rUTAH

+expmap *-expmap*

3yrs

15 classes

All learning strategies are doing better than chance…



Animacy

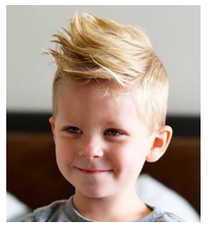
Syntactic frame

-1.0 <= ARI <= 1.0

<4yrs

23 classes

<5yrs



24 classes

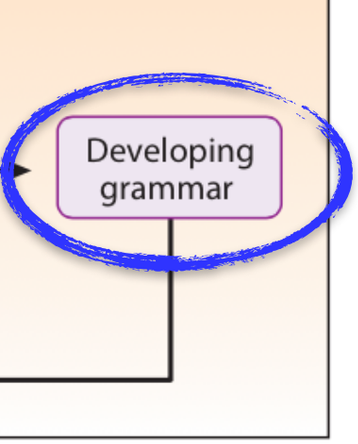
+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH		rUTAH		UTAH		rUTAH		
+expmap	*-expmap*	*+expmap*	*-expmap*	*+expmap*	*-expmap*	*+expmap*	*-expmap*	
0.053	0.063	0.050	0.144	**0.213**	**0.238**	**0.221**	**0.193**	 **3yrs** **15 classes**

But some are clearly doing better than others.

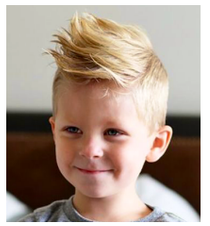


Animacy

Syntactic frame

-1.0 <= ARI <= 1.0

<5yrs



24 classes

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH

+expmap

-expmap

rUTAH

+expmap

-expmap

UTAH

+expmap

-expmap

rUTAH

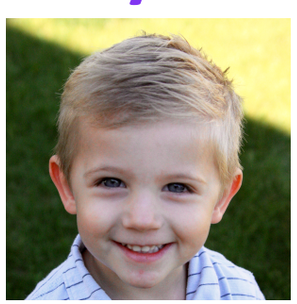
+expmap

-expmap

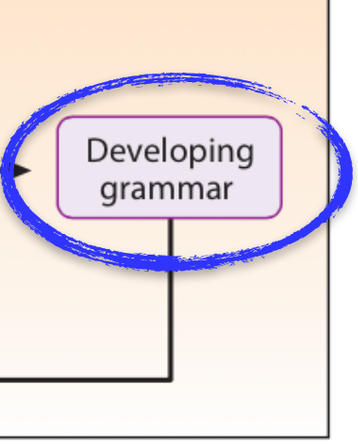
3yrs

15 classes

<4yrs



23 classes

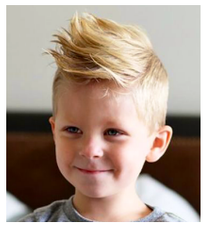


Animacy

Syntactic frame

-1.0 <= ARI <= 1.0

<5yrs



24 classes

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH

+expmap *-expmap*

rUTAH

+expmap *-expmap*

UTAH

+expmap *-expmap*

rUTAH

+expmap *-expmap*

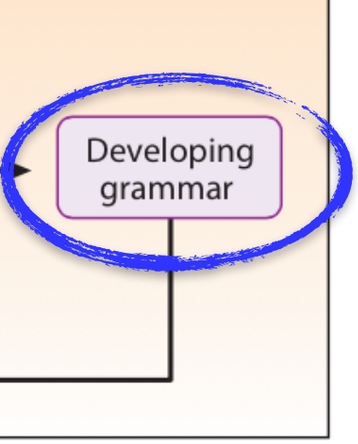
3yrs

15 classes

4yrs

23 classes

All learning strategies are doing better than chance…

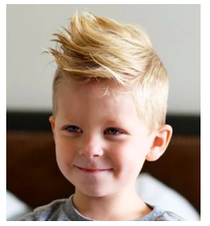


Animacy

Syntactic frame

-1.0 <= ARI <= 1.0

<5yrs



24 classes

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH		rUTAH		UTAH		rUTAH	
+expmap	*-expmap*	*+expmap*	*-expmap*	*+expmap*	*-expmap*	*+expmap*	*-expmap*
0.143	**0.261**	0.080	0.103	0.102	0.091	0.090	0.120

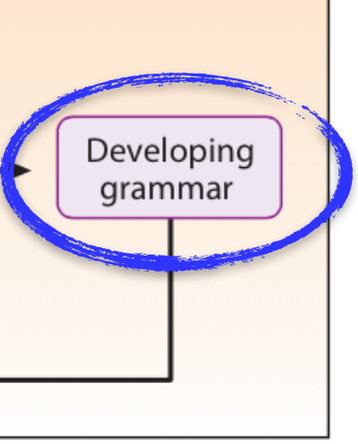
3yrs

15 classes

4yrs

23 classes

But one is clearly doing better than others.



Animacy

-1.0 <= ARI <= 1.0

Syntactic frame

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH

+expmap

-expmap

rUTAH

+expmap

-expmap

UTAH

+expmap

-expmap

rUTAH

+expmap

-expmap

3yrs

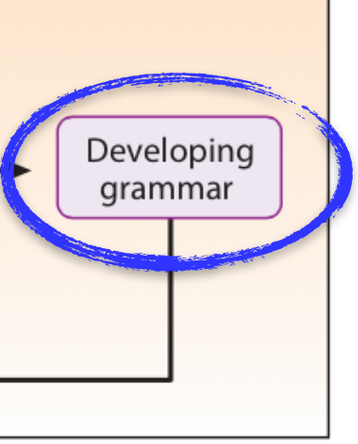
15 classes

4yrs

23 classes

<5yrs

24 classes



Animacy

Syntactic frame

-1.0 <= ARI <= 1.0

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH

+expmap *-expmap*

rUTAH

+expmap *-expmap*

UTAH

+expmap *-expmap*

rUTAH

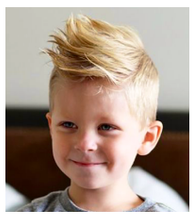
+expmap *-expmap*

3yrs

15 classes

4yrs

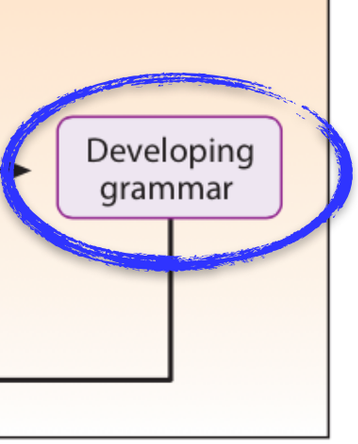
23 classes



5yrs

24 classes

All learning strategies are doing better than chance…



Animacy

Syntactic frame

-1.0 <= ARI <= 1.0

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH

+expmap *-expmap*

rUTAH

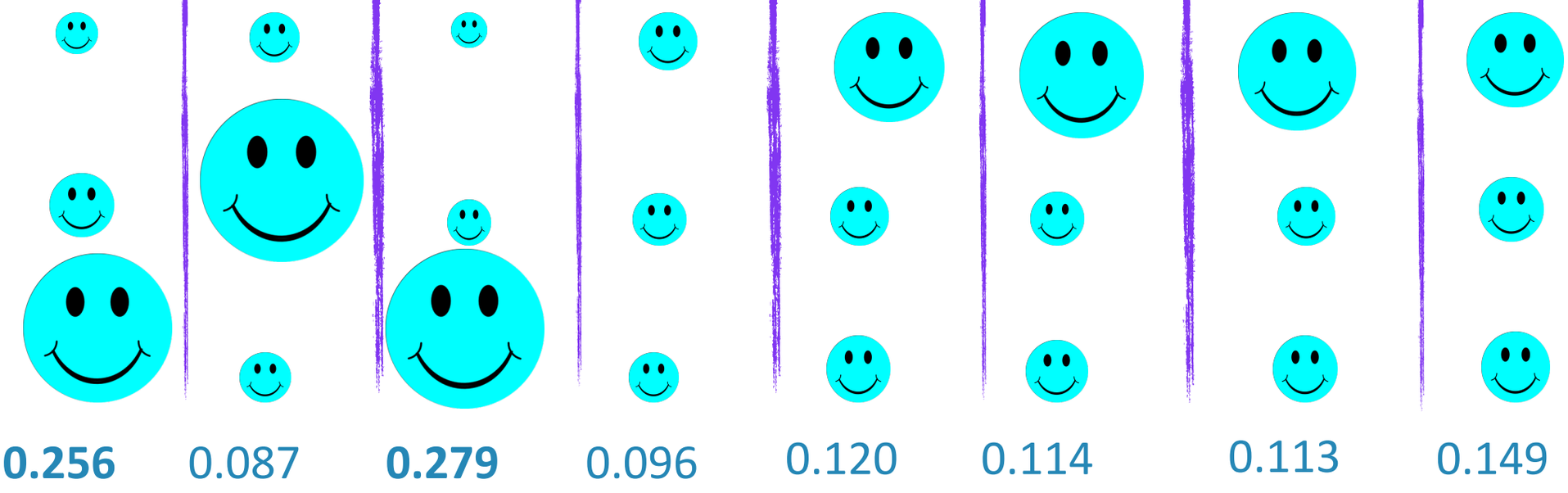
+expmap *-expmap*

UTAH

+expmap *-expmap*

rUTAH

+expmap *-expmap*



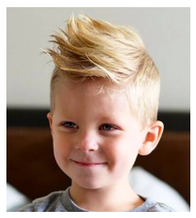
0.256 0.087 **0.279** 0.096 0.120 0.114 0.113 0.149

3yrs

15 classes

4yrs

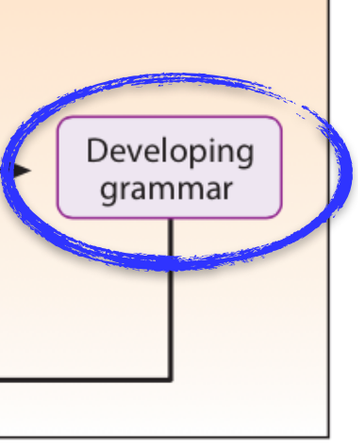
23 classes



5yrs

24 classes

But two are clearly doing better than others.



Animacy

Syntactic frame

-1.0 <= ARI <= 1.0

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH

+expmap

-expmap

rUTAH

+expmap

-expmap

UTAH

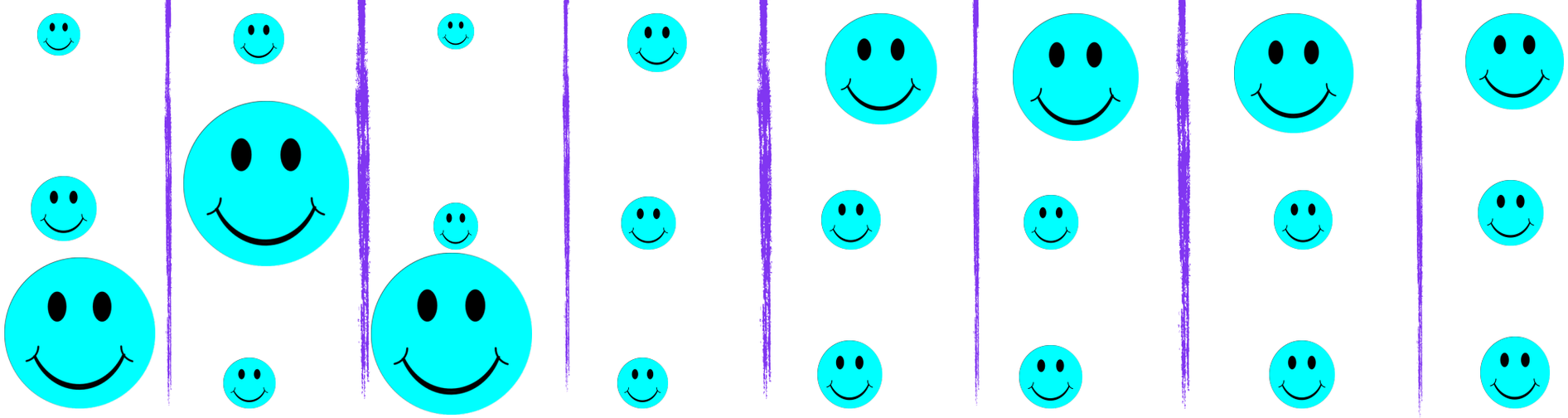
+expmap

-expmap

rUTAH

+expmap

-expmap

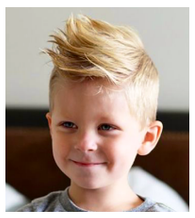


3yrs

15 classes

4yrs

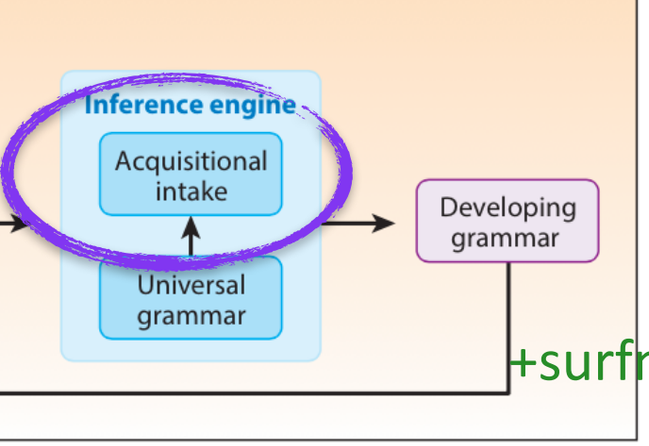
23 classes



5yrs

24 classes

What does this mean?



-1.0 <= ARI <= 1.0

-surfmorph

UTAH

+expmap *-expmap*

rUTAH

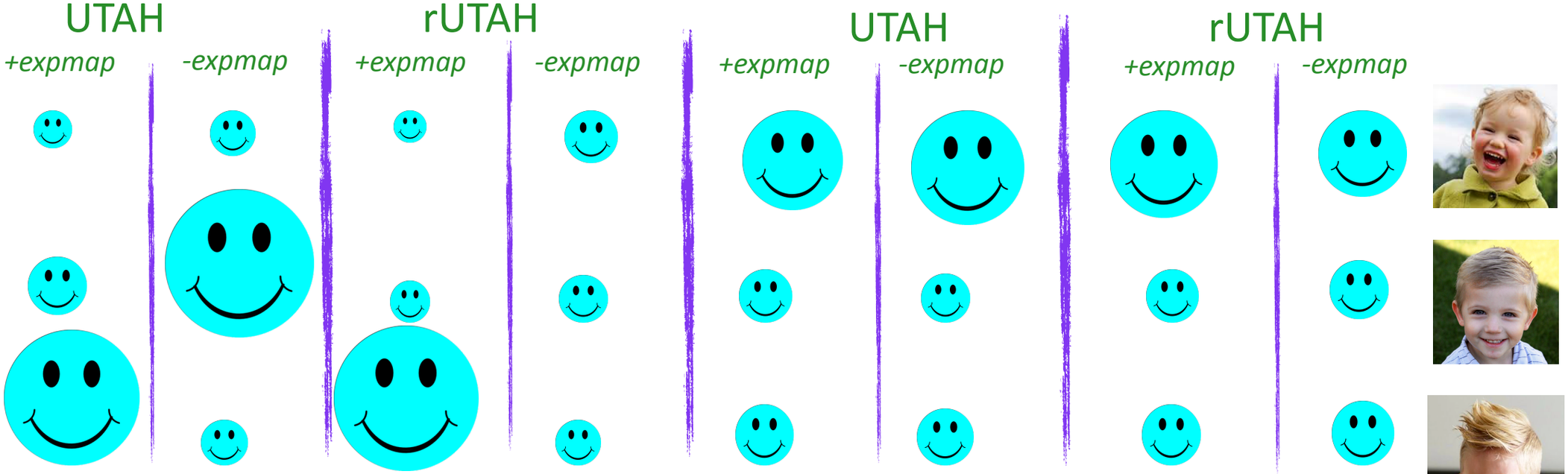
+expmap *-expmap*

UTAH

+expmap *-expmap*

rUTAH

+expmap *-expmap*

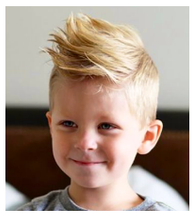


3yrs

15 classes

4yrs

23 classes



5yrs

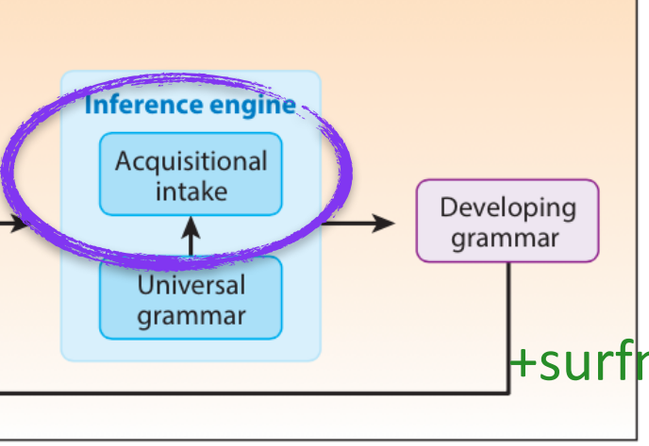
24 classes

Animacy

Syntactic frame

Thematic roles and how to use them

Using animacy, syntactic frame, and thematic role information is a pretty good match for what children seem to be doing when creating verb classes.



Animacy

Syntactic frame

-surfmorph

Thematic roles and how to use them

UTAH

+expmap *-expmap*

rUTAH

+expmap *-expmap*

UTAH

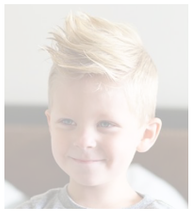
+expmap *-expmap*

rUTAH

+expmap *-expmap*

4yrs

23 classes



5yrs

24 classes

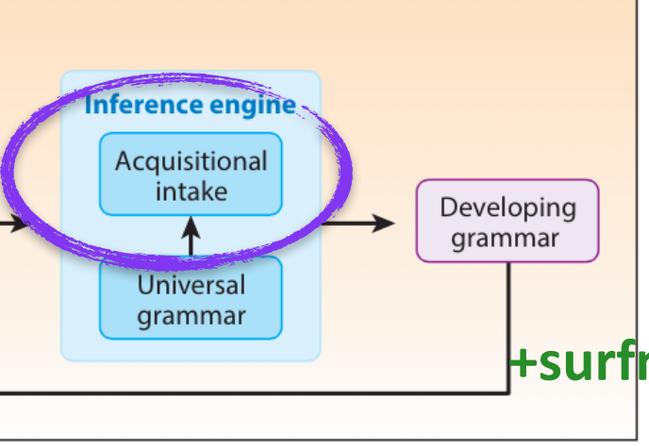
3yrs

Syntactic frame

The ice seemed to melt.

NP ___ $S_{nonfinite}$ -surfmorph

Before 3, children ignore verb morphology but may be using any of the options for thematic roles.

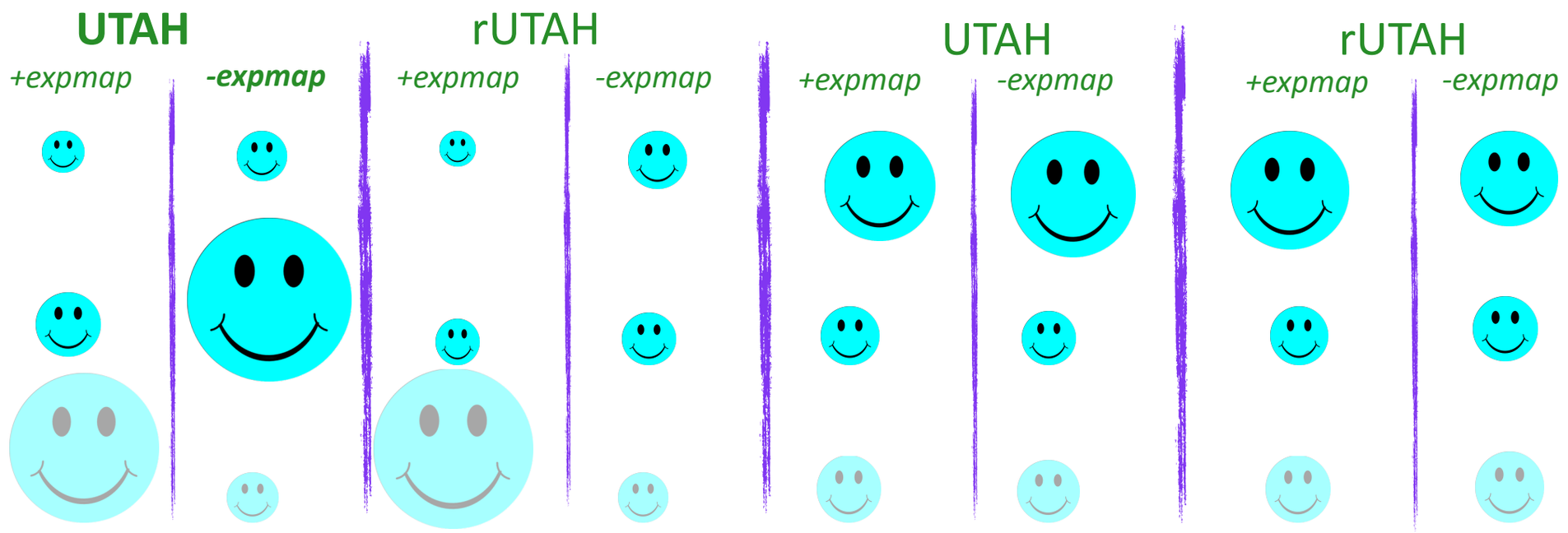


Animacy

Syntactic frame

+surfmorph -surfmorph

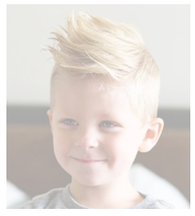
Thematic roles and how to use them



3yrs

-surfmorph

4yrs



5yrs

24 classes

By 4, children heed verb morphology, are using the UTAH intermediate representation, and don't expect a mapping a priori.

UTAH

Thematic roles

and how to use them

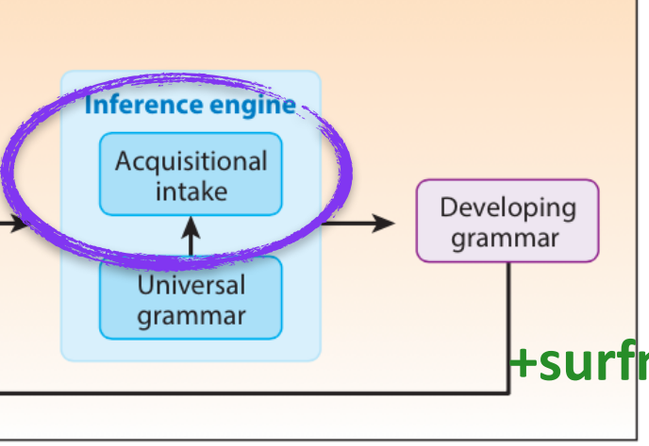
-expmap

Subject ***Object*** ***Indirect Object***

Syntactic frame

+surfmorph **The ice** seemed to melt.

NP ____**+past** $S_{nonfinite}$



Animacy

Syntactic frame

+surfmorph

-surfmorph

Thematic roles and how to use them

UTAH

+expmap

-expmap

rUTAH

+expmap

-expmap

UTAH

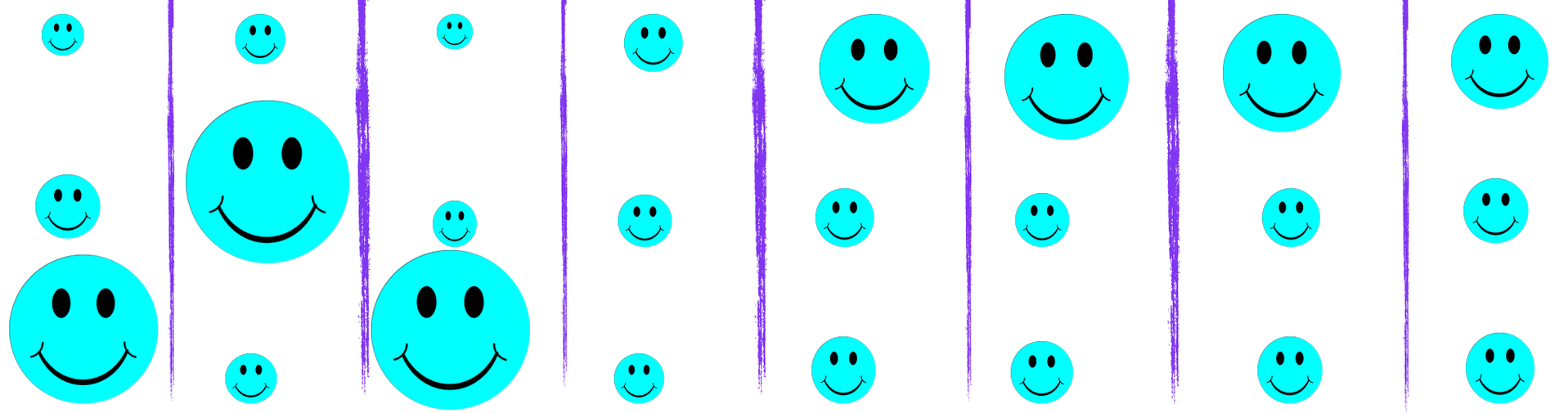
+expmap

-expmap

rUTAH

+expmap

-expmap



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

By 5, children still heed verb morphology, but now may be using either the UTAH or rUTAH representation and expect a mapping.

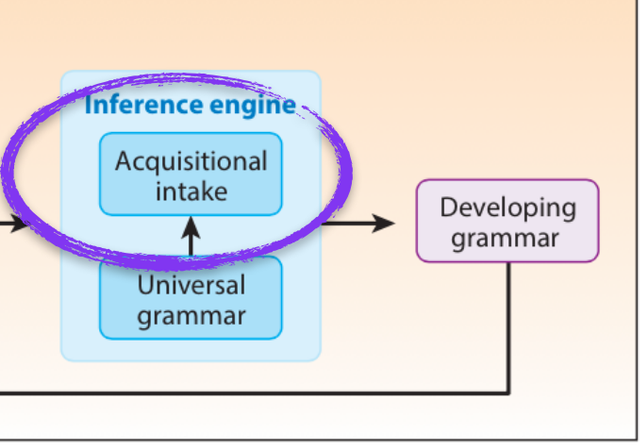
UTAH

rUTAH **Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)**

+expmap

Subject ***Object*** ***Indirect Object***

movement?



-animate

The ice seemed to melt.

NP ___ $S_{nonfinite}$

3yrs

-surfmorph

Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)

?

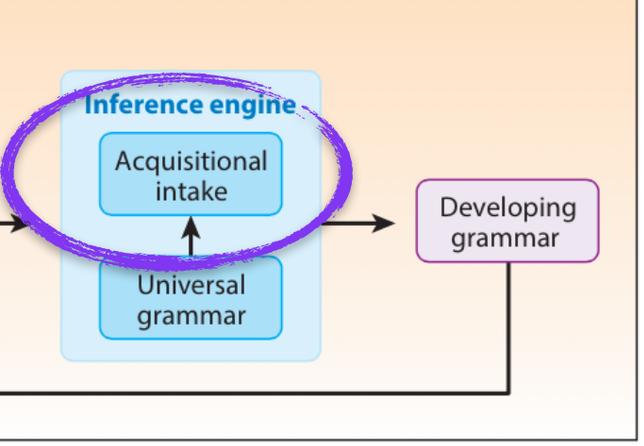
Subject ***Object*** ***Indirect Object***

4yrs

+surfmorph
UTAH
-expmap

5yrs

+surfmorph
UTAH rUTAH
+expmap



-animate

Subject

The ice seemed to melt.

NP ____+past S nonfinite

Subject ***Object*** ***Indirect Object***

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

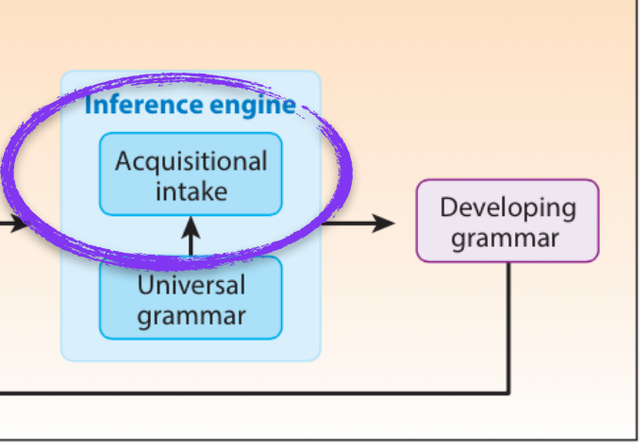
-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap



-animate
Subject

The ice seemed to melt.

NP ____ +past $S_{nonfinite}$

+movement

Highest *-movement*
Theme

Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)

3yrs

-surfmorph

4yrs

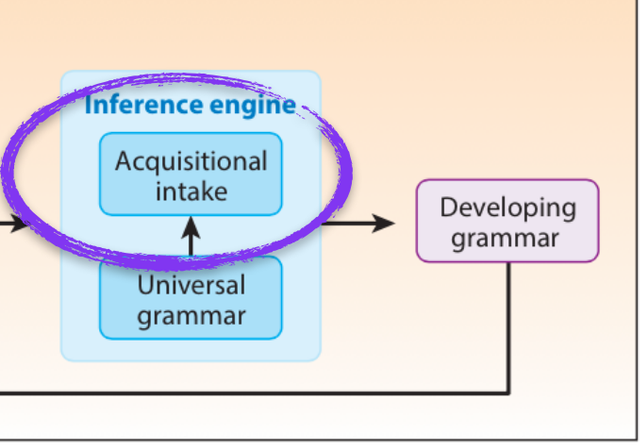
+surfmorph

UTAH
-expmap

5yrs

+surfmorph

UTAH rUTAH
+expmap



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

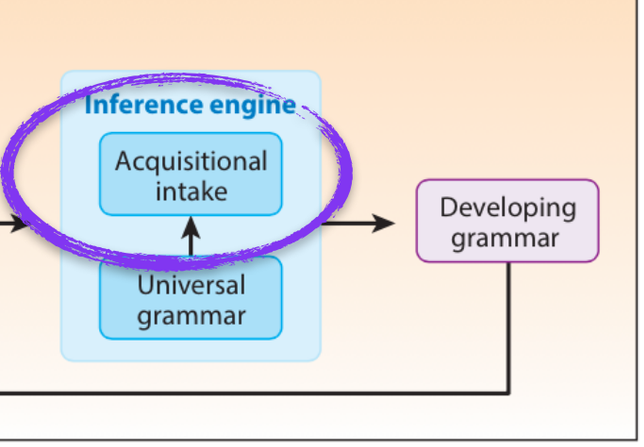
5yrs

+surfmorph

UTAH rUTAH

+expmap

This is the first articulation of the trajectory of learning assumptions children may have that causes them to group verbs into useful classes the way we observe.



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

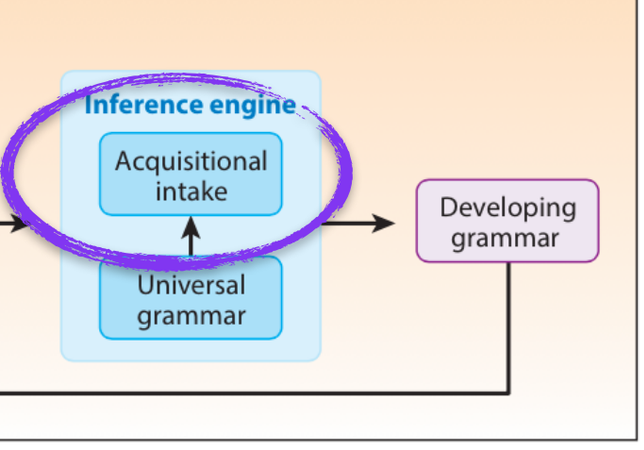
UTAH rUTAH

+expmap

The ice seemed to melt. NP ___ $S_{nonfinite}$ NP ____**+past** $S_{nonfinite}$

It suggests there are different timelines for

- ignoring vs. heeding surface morphology on verbs …



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH **rUTAH**

+expmap

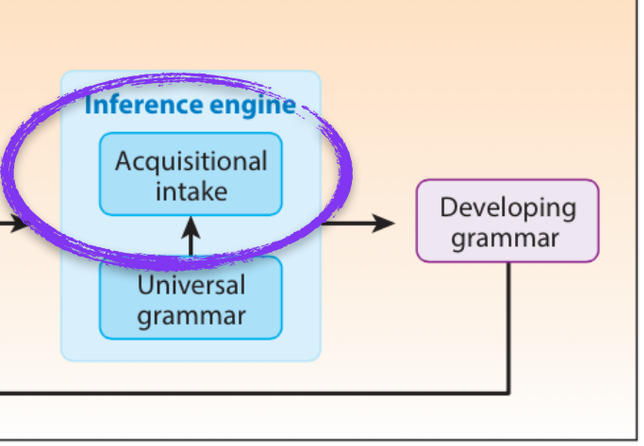
Agent > Experiencer >

Theme > Patient >

(Source, Goal, Instrument)

It suggests there are different timelines for

- ignoring vs. heeding surface morphology on verbs
- **a simpler vs. more flexible intermediate thematic representation…**



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap

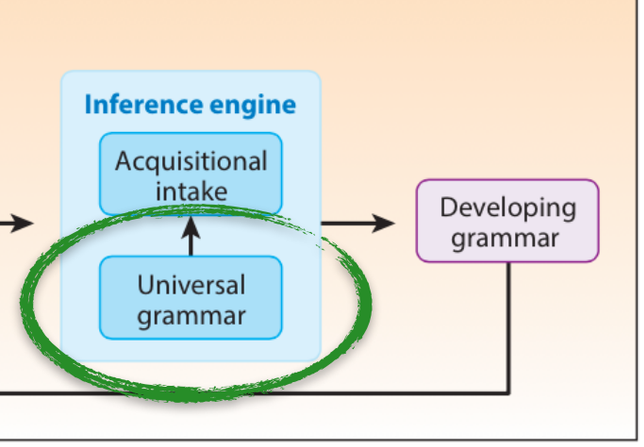
Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

movement?

Subject ***Object*** ***Indirect Object***

It suggests there are different timelines for

- ignoring vs. heeding surface morphology on verbs
- a simpler vs. more flexible intermediate thematic representation
- **not expecting vs. expecting a mapping between that intermediate thematic representation and syntactic positions**



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap

What does this mean for linguistic theory?

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

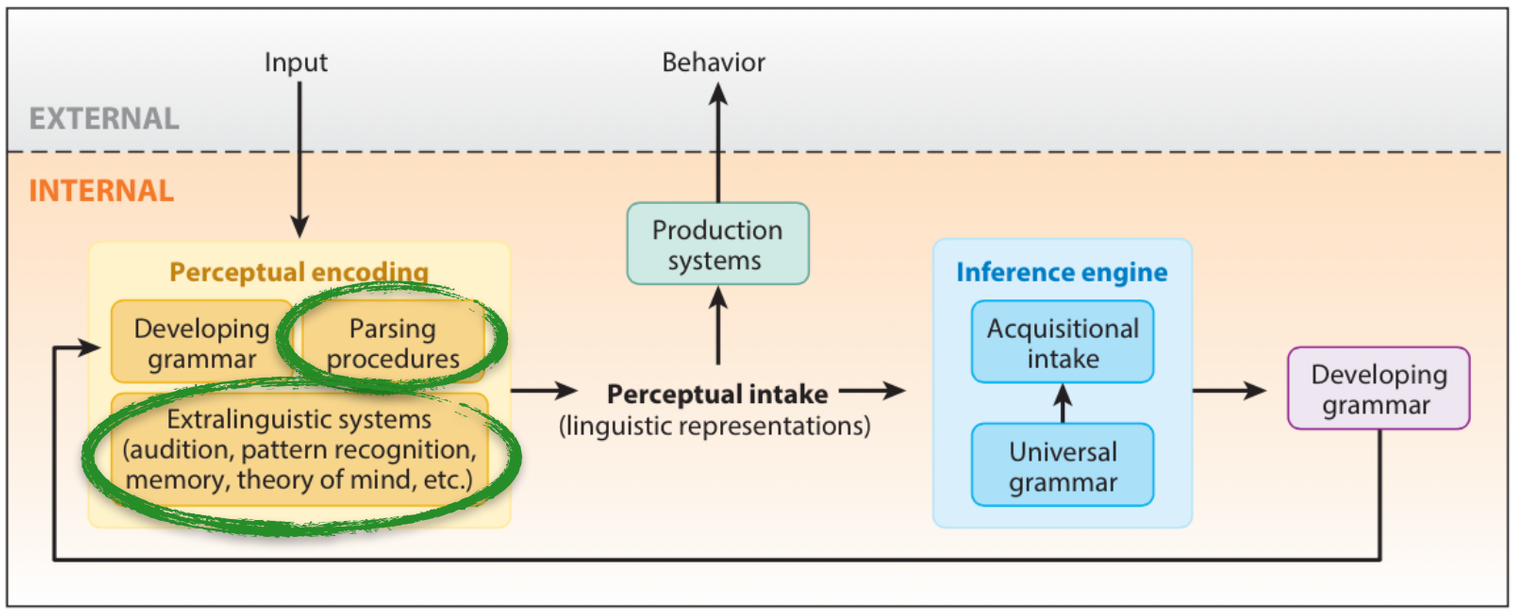
+surfmorph

UTAH rUTAH

+expmap

What seems to develop earlier
(perhaps because it's easy to derive from existing biases):

-surfmorph: Preference to ignore surface morphology
(perhaps due to processing limitations)



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

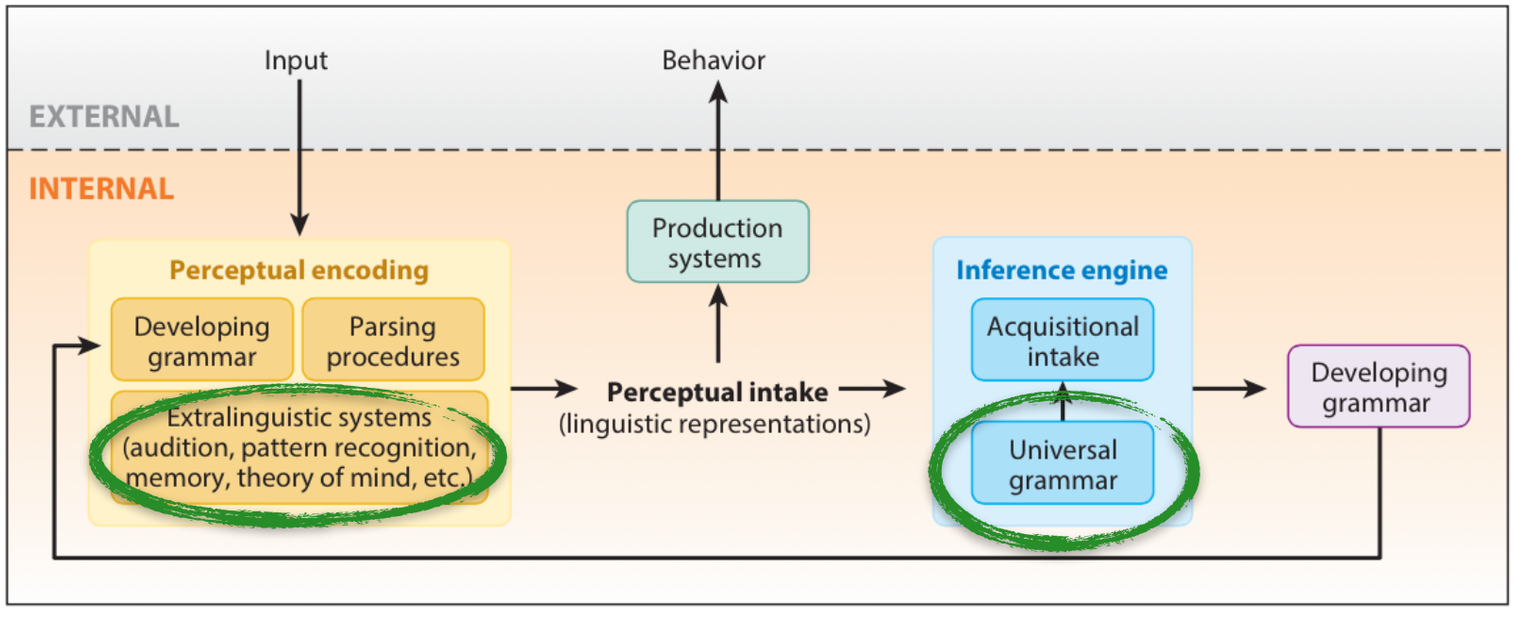
+surfmorph

UTAH rUTAH

+expmap

What seems to develop somewhat earlier (perhaps because it's easy to derive from existing biases):

UTAH: Simpler thematic representation



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

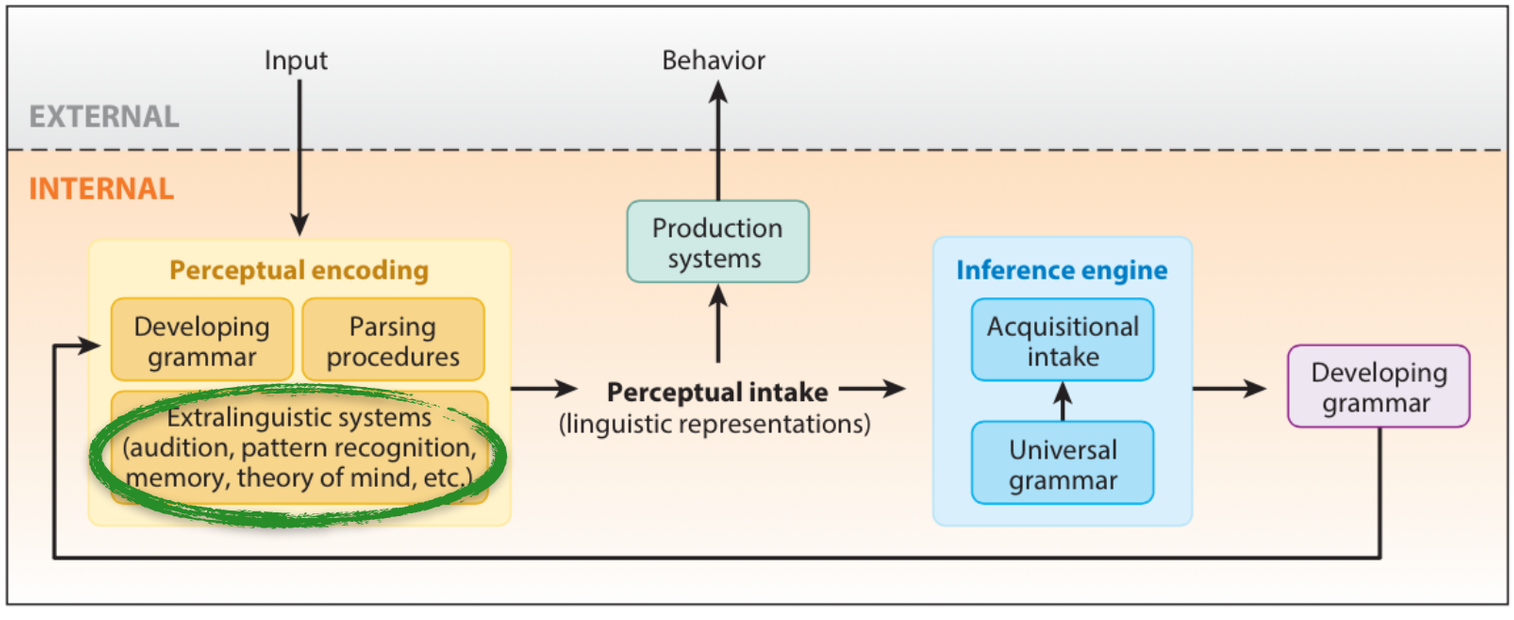
UTAH rUTAH

+expmap

What seems to develop somewhat earlier (perhaps because it's easy to derive from existing biases):

Subject *Object* *Indirect Object*

-expmap: No prior expectation about how to map — learn this from the intake



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH **rUTAH**

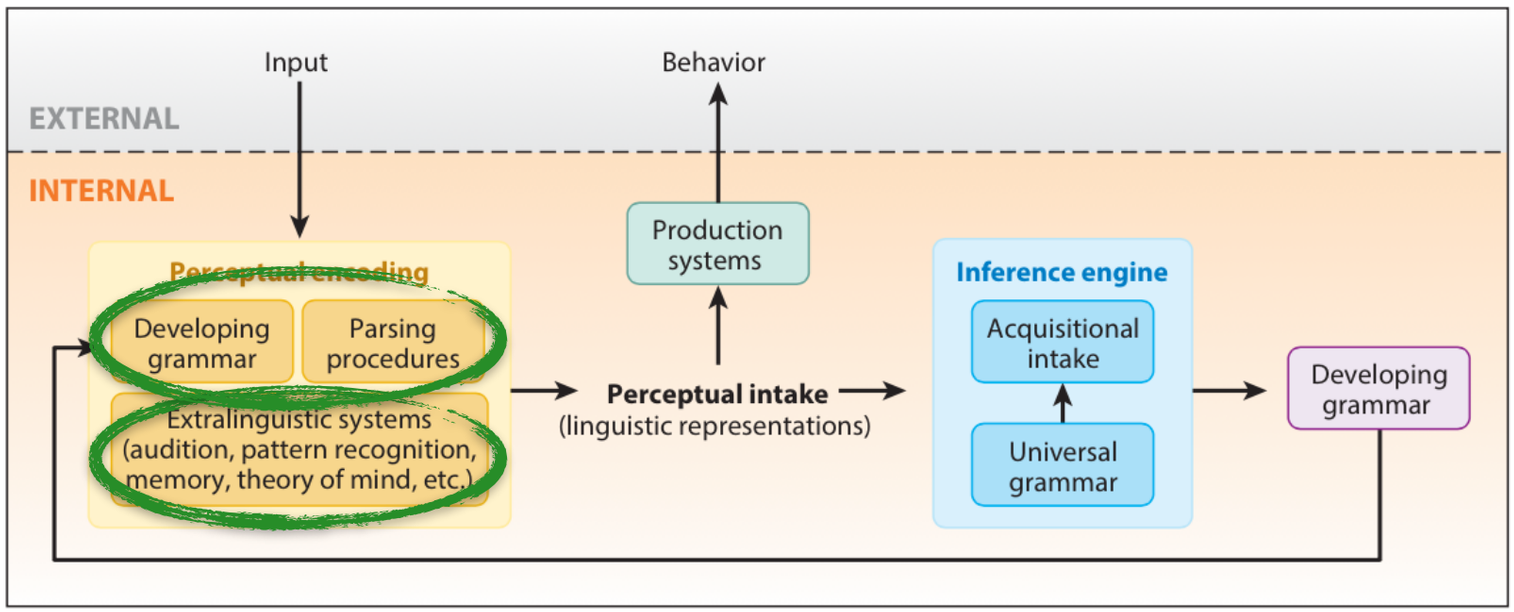
+expmap

Subject ***Object*** ***Indirect Object***

Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)

What seems to develop later (perhaps building on prior knowledge):

rUTAH: more sophisticated thematic representation



3yrs

-surfmorph

4yrs

+surfmorph

UTAH

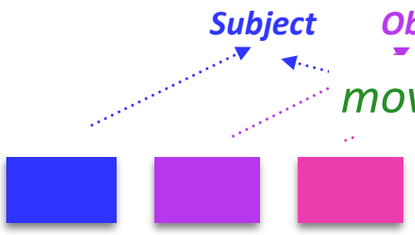
-expmap

5yrs

+surfmorph

UTAH rUTAH

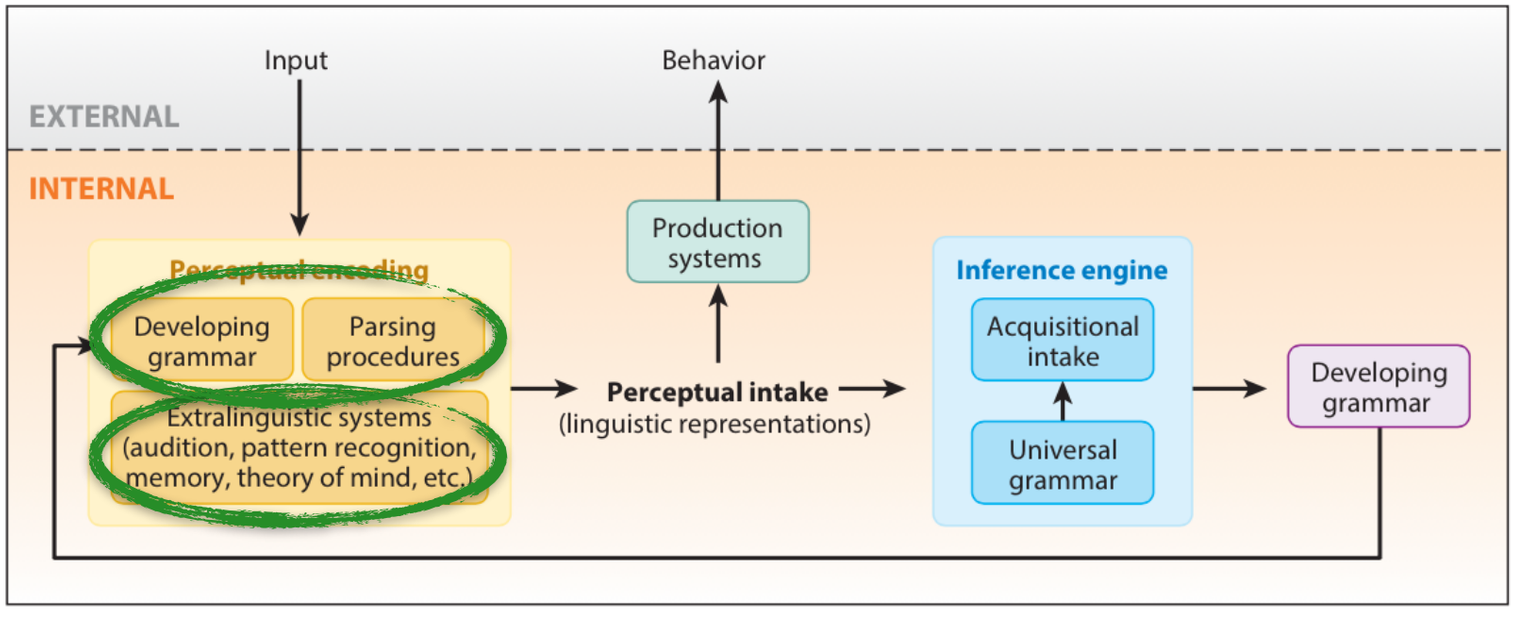
+expmap

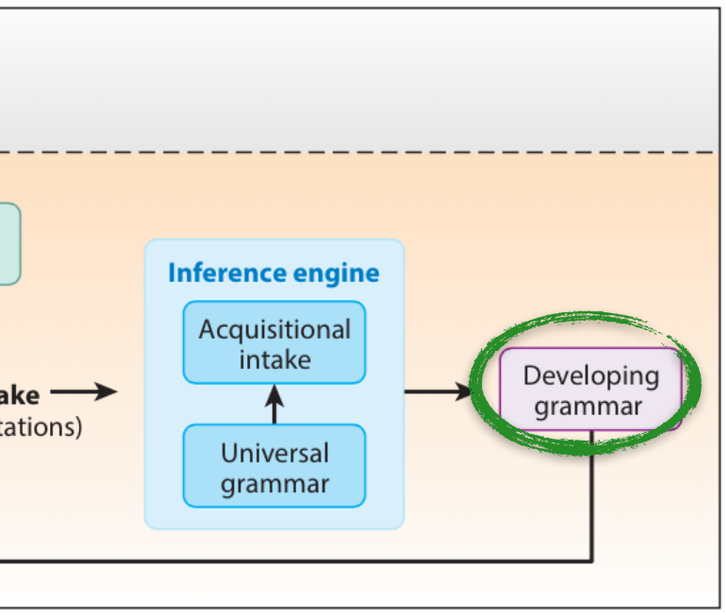


Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)

What seems to develop later (perhaps building on prior knowledge and the intake):

+expmap: an expectation for a mapping between that representation and grammatical positions





Bigger theoretical takeaway:

Everyone's right about the representation at some stage of development.

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap

-surfmorph

NP ___ $S_{nonfinite}$

+animate

+surfmorph

NP ____**+past** $S_{nonfinite}$

UTAH

rUTAH **Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)**

-expmap ***Subject*** ***Object*** ***Indirect Object***

+expmap *movement?*

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap

So now what?

So now what?

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap

(1) A broader assessment of children's verb class knowledge

So now what?

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap

(1) A broader assessment of children's verb class knowledge

We need more observable behavior for verbs in children's input to match modeling results against.

<3yrs

239 verbs

15 classes

of 60 verbs

<4yrs

267 verbs

23 classes

of 76 verbs

<5yrs

284 verbs

24 classes

of 82 verbs

Input

Children's behavior

So now what?

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap

(1) A broader assessment of children's verb class knowledge

This will further test these theoretical proposals, and validate (or not) the current findings.

<3yrs

239 verbs

15 classes

of 60 verbs

<4yrs

267 verbs

23 classes

of 76 verbs

<5yrs

284 verbs

24 classes

of 82 verbs

Input

Children's behavior

So now what?

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap

(1) A broader assessment of children's verb class knowledge

(a) More verbs

<3yrs

239 verbs

15 classes

of 60 verbs

<4yrs

267 verbs

23 classes

of 76 verbs

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284 verbs

24 classes

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Input

Children's behavior

So now what?

3yrs

-surfmorph

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UTAH

-expmap

5yrs

+surfmorph

UTAH rUTAH

+expmap

(1) A broader assessment of children's verb class knowledge

(a) More verbs

<3yrs

239 verbs

15 classes

of 60 verbs

<4yrs

267 verbs

23 classes

of 76 verbs

<5yrs

284 verbs

24 classes

of 82 verbs

(b) More behaviors

transitive

unergative

intransitive

non-finite -ing

small clause

wager-class

Input

Children's behavior

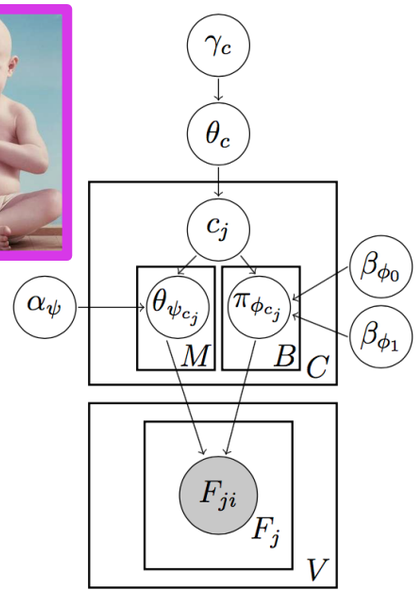
So now what?

(1) A broader assessment of children's verb class knowledge

experimental

3yrs	4yrs	5yrs
-surfmorph	+surfmorph	+surfmorph
	UTAH	UTAH rUTAH
	-expmap	+expmap

(2) Models incorporating more cognitively plausible assumptions



This may give us an even better match to children's observed verb class behavior.

So now what?

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

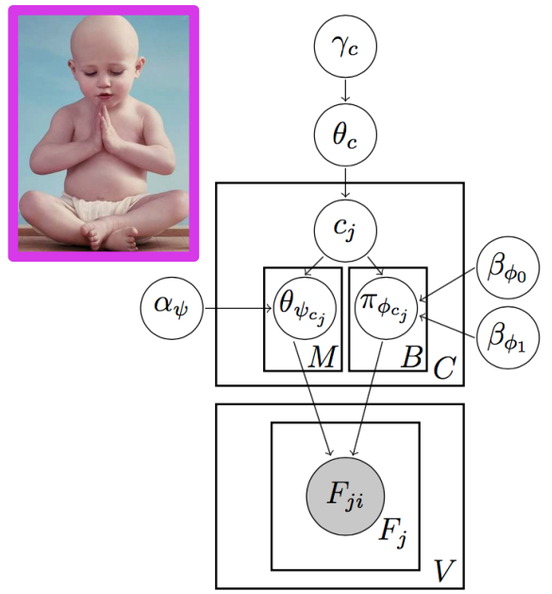
UTAH rUTAH

+expmap

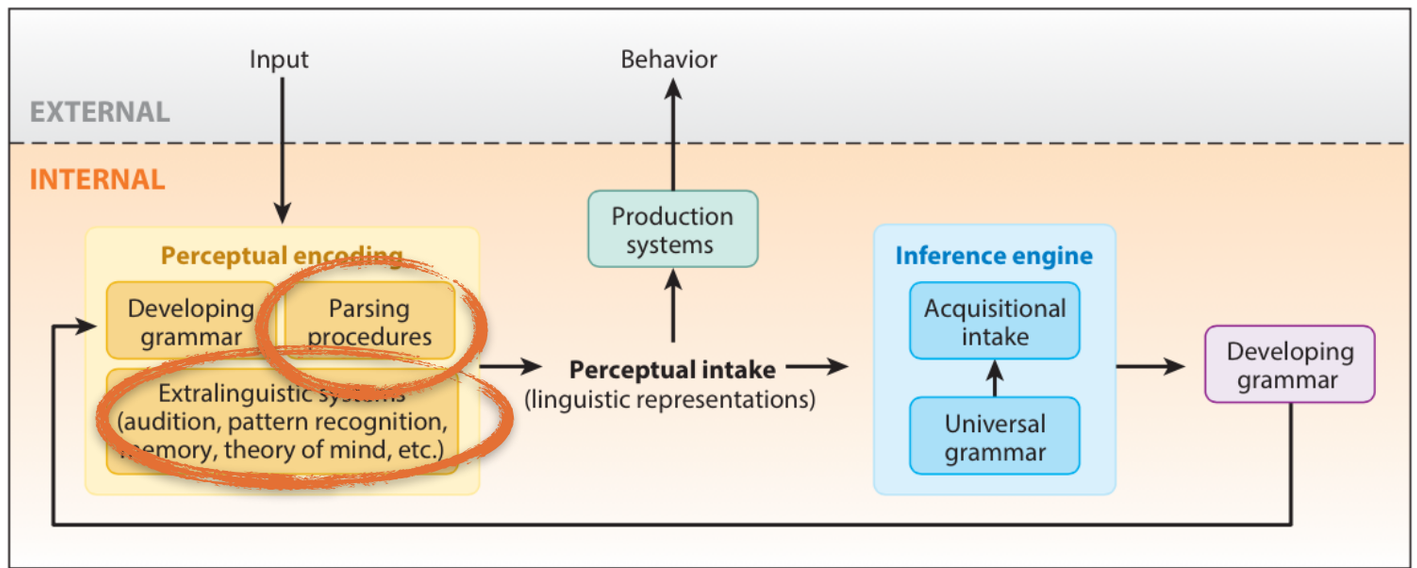
(1) A broader assessment of children's verb class knowledge

experimental

(2) Models incorporating more cognitively plausible assumptions



What happens when we embed these theories in a learning model that learns incrementally and has age-appropriate memory & processing limitations?



So now what?

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

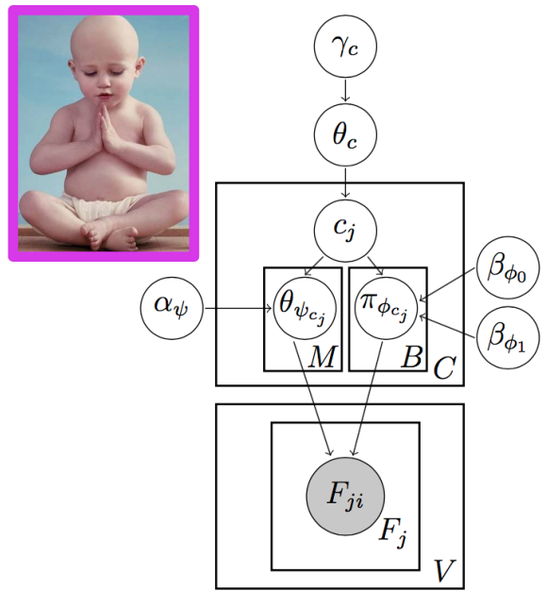
UTAH rUTAH

+expmap

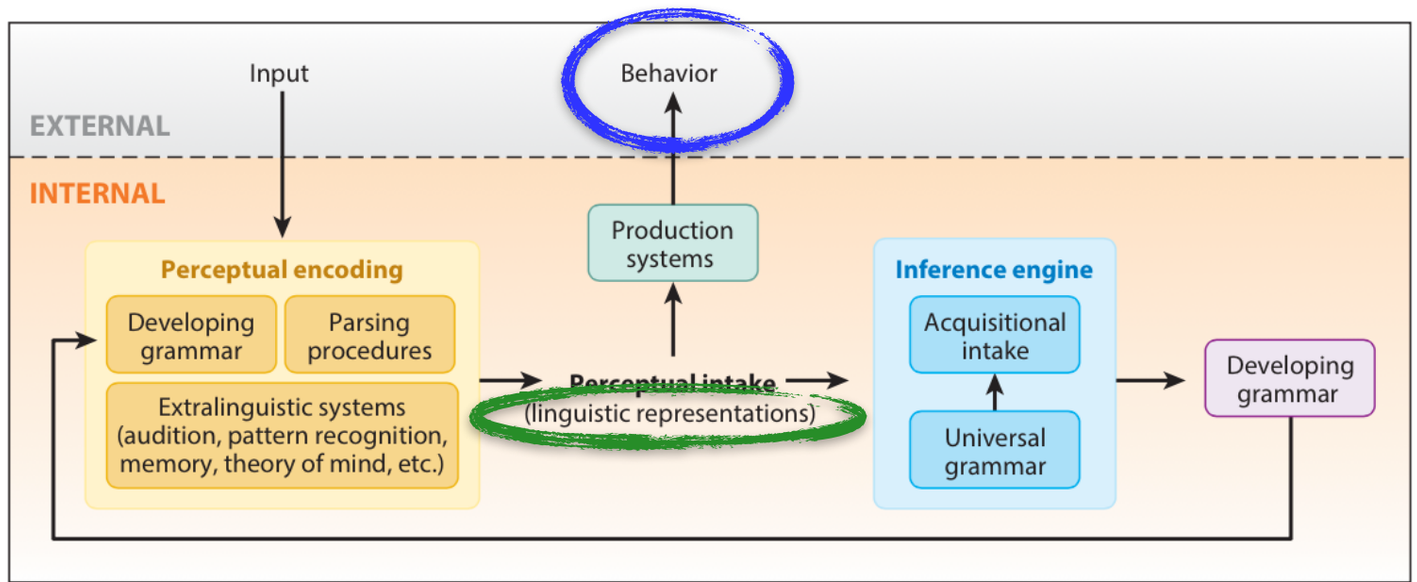
(1) A broader assessment of children's verb class knowledge

experimental

(2) Models incorporating more cognitively plausible assumptions



What kinds of child behavior does the model predict in the experimental scenarios already available, based on its internal representations?



So now what?

3yrs

-surfmorph

4yrs

+surfmorph

UTAH

-expmap

5yrs

+surfmorph

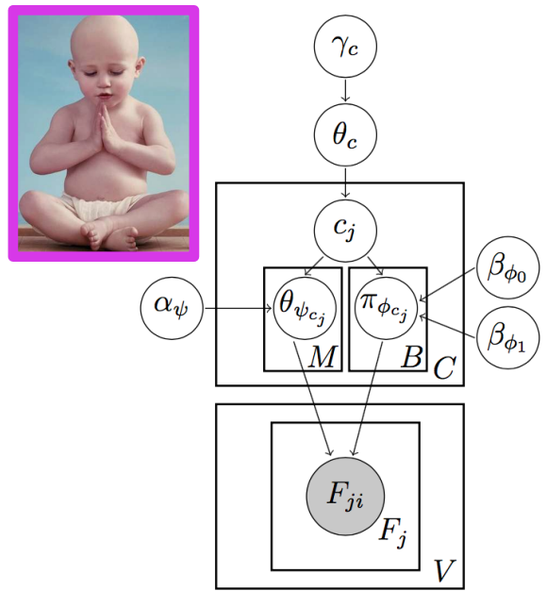
UTAH rUTAH

+expmap

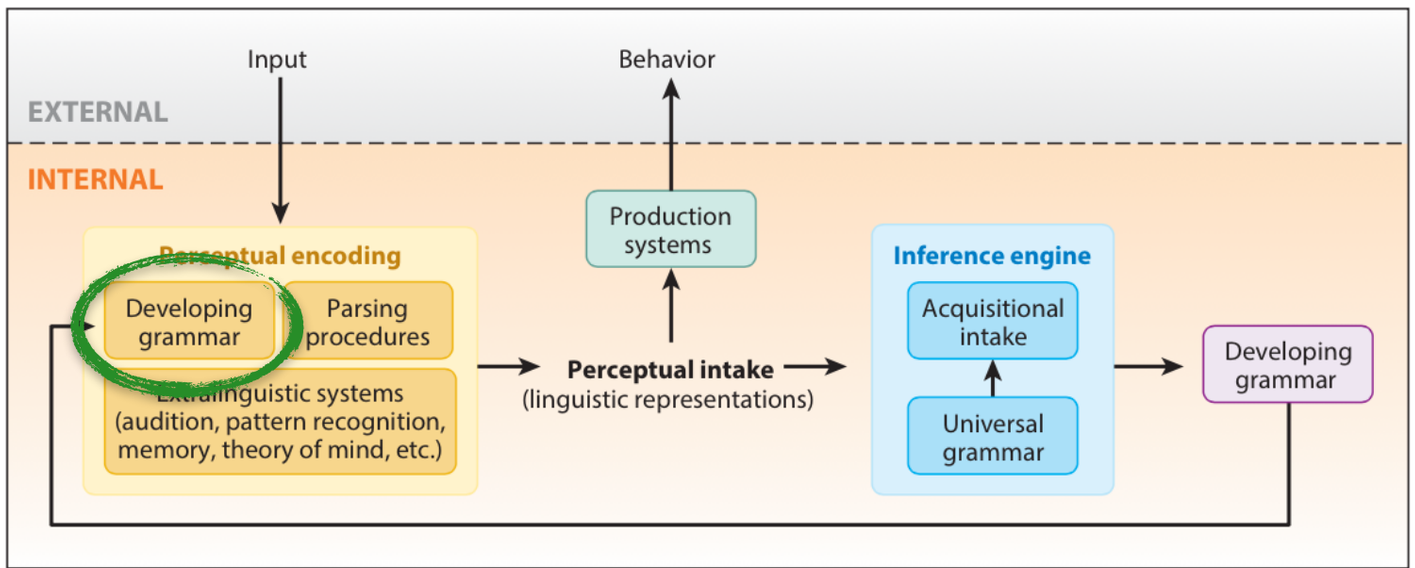
(1) A broader assessment of children's verb class knowledge

experimental

(2) Models incorporating more cognitively plausible assumptions



What other types of information may be available, especially throughout development as children learn from their intake?



So now what?

3yrs

-surfmorph

4yrs

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UTAH

-expmap

5yrs

+surfmorph

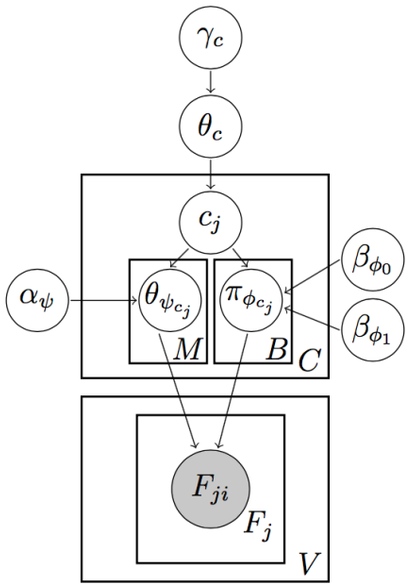
UTAH rUTAH

+expmap

(1) A broader assessment of children's verb class knowledge

experimental

(2) Models incorporating more cognitively plausible assumptions



computational

(3) Other theories of representation

Are there other options for linking thematic role information to syntactic structure that we can explore in this framework?

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

Subject ***Object*** ***Indirect Object***

???

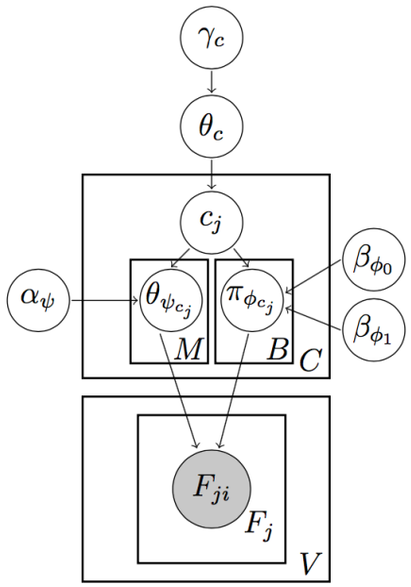
So now what?

3yrs	4yrs	5yrs
-surfmorph	+surfmorph	+surfmorph
	UTAH	UTAH rUTAH
	-expmap	+expmap

(1) A broader assessment of children's verb class knowledge

experimental

(2) Models incorporating more cognitively plausible assumptions



computational

(3) Other theories of representation

Agent > Experiencer > Theme > Patient > (Source, Goal, Instrument)

???

theoretical

Subject ***Object*** ***Indirect Object***

What we saw today

Verb classes

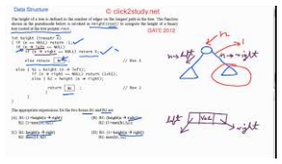
done-to

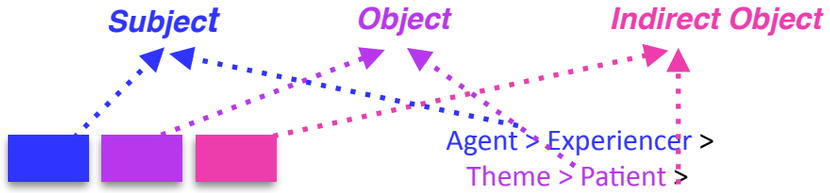
The ice melted.

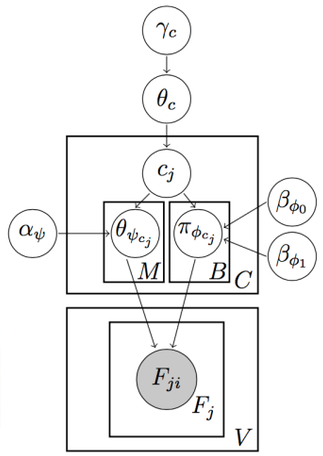
The penguin climbed.

doer

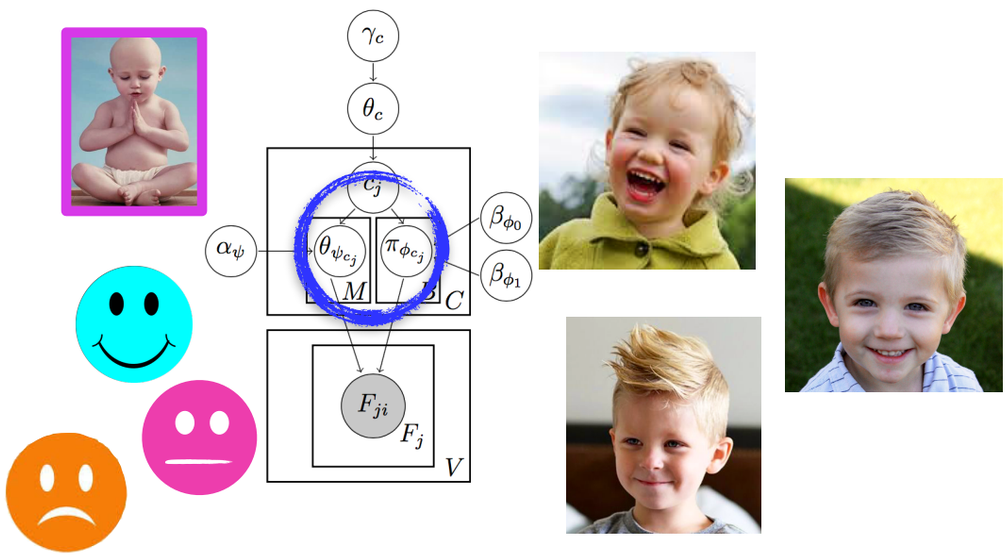
Computational modeling







Results & implications



What we saw today

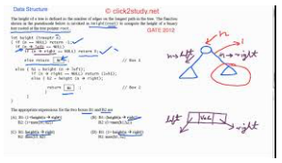
done-to

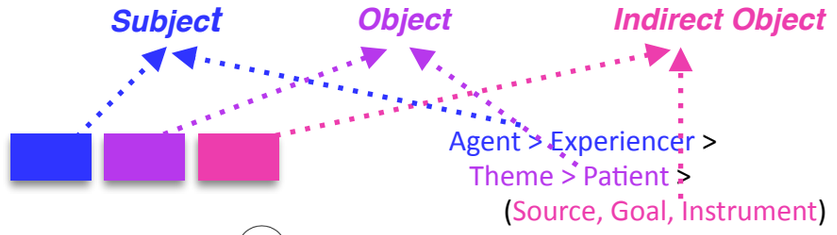
The ice melted.
The penguin climbed.

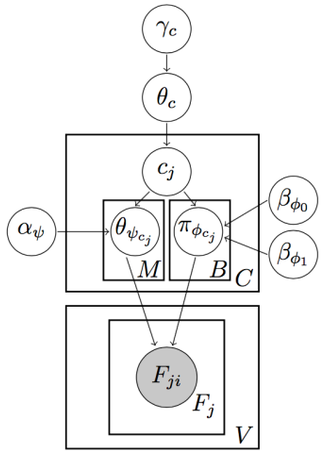
doer

Verb classes: An example of complex linguistic knowledge that children develop, involving several theoretical options for the representations they may be using.

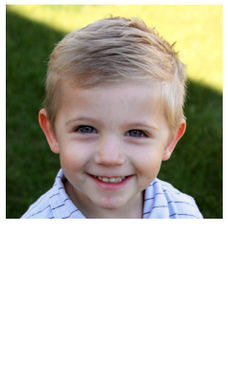
Computational modeling







Results & implications



What we saw today

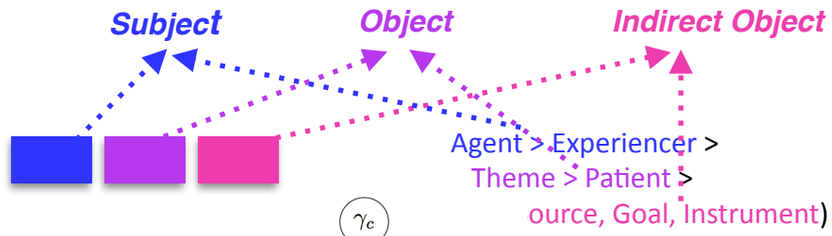
done-to

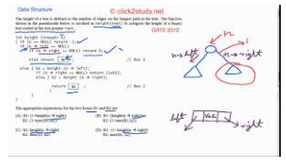
The ice melted.
The penguin climbed.

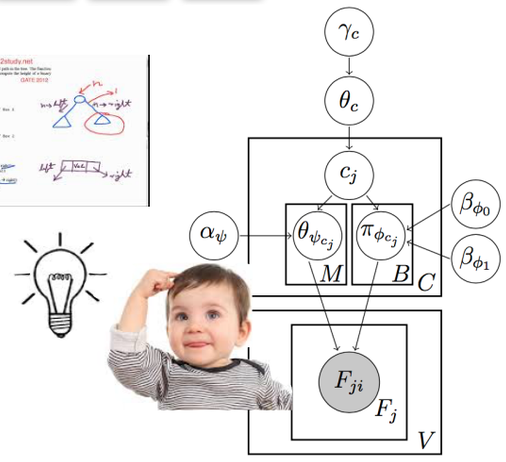
doer

Verb classes: complex linguistic knowledge involving several theoretical options for representations

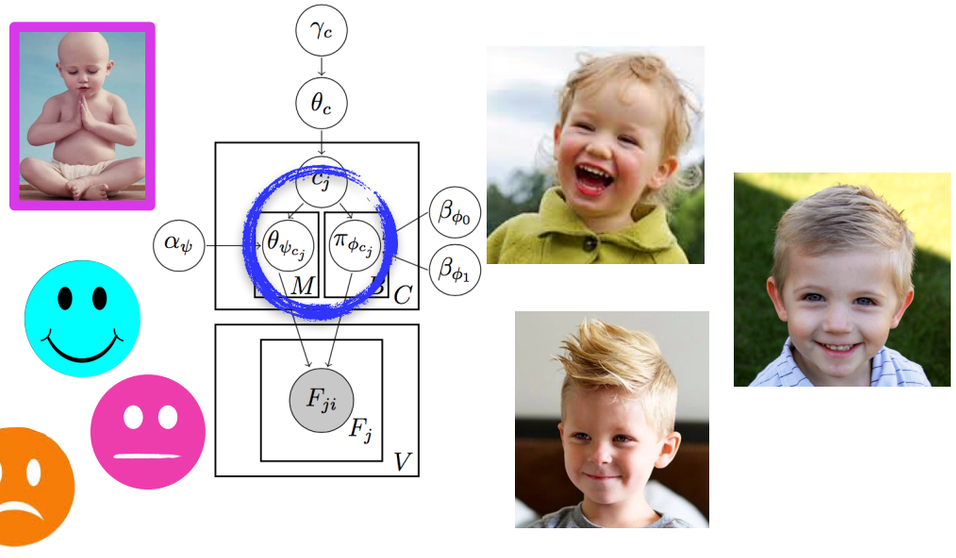
Computational modeling: A way to explicitly test these theories by implementing them concretely in an empirically grounded model of the acquisition process.







Results & implications



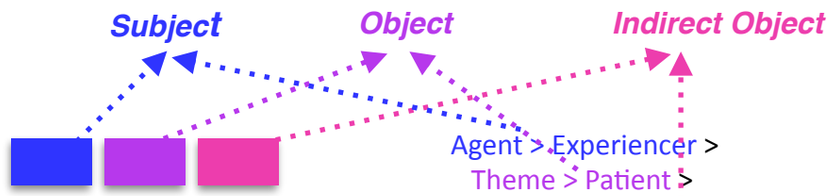
What we saw today

done-to

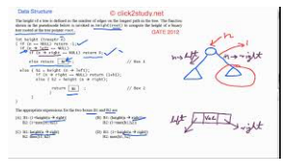
The ice melted.
The penguin climbed.

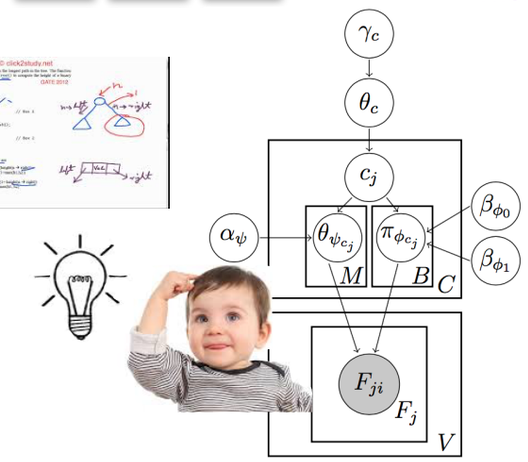
doer

Verb classes: complex linguistic knowledge involving several theoretical options for representations

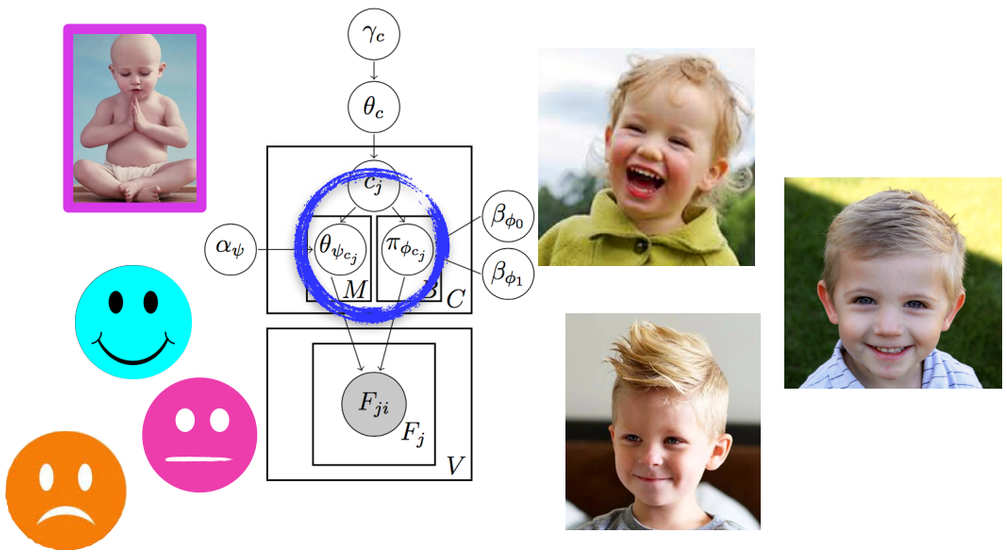


Computational modeling: explicitly test these theories





Results & implications: Articulating the trajectory of representations and learning assumptions children have at different stages of development



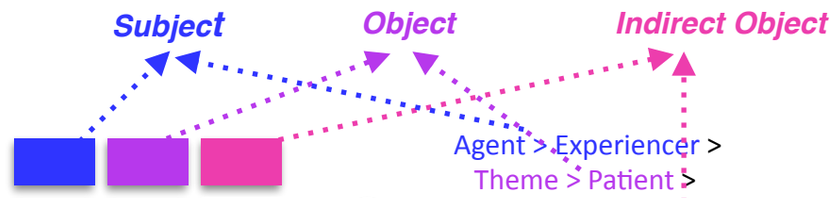
What we saw today

done-to

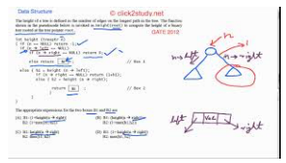
The ice melted.
The penguin climbed.

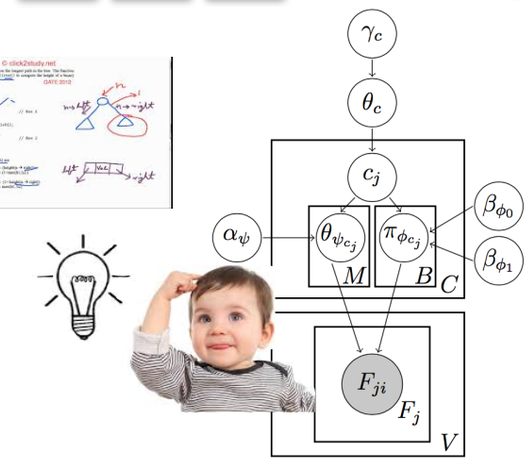
doer

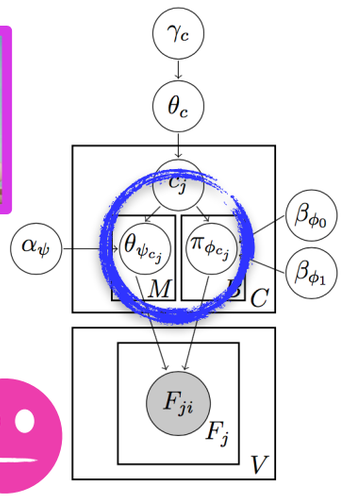
Verb classes: complex linguistic knowledge involving several theoretical options for representations



Computational modeling: explicitly test these theories







Results & implications: Articulating the representational trajectory over development

This approach allows us to connect theories of linguistic representation and theories of language acquisition to understand more about both.

Thank you!

Jon Sprouse

SynLinks workshop 2016

McGill University

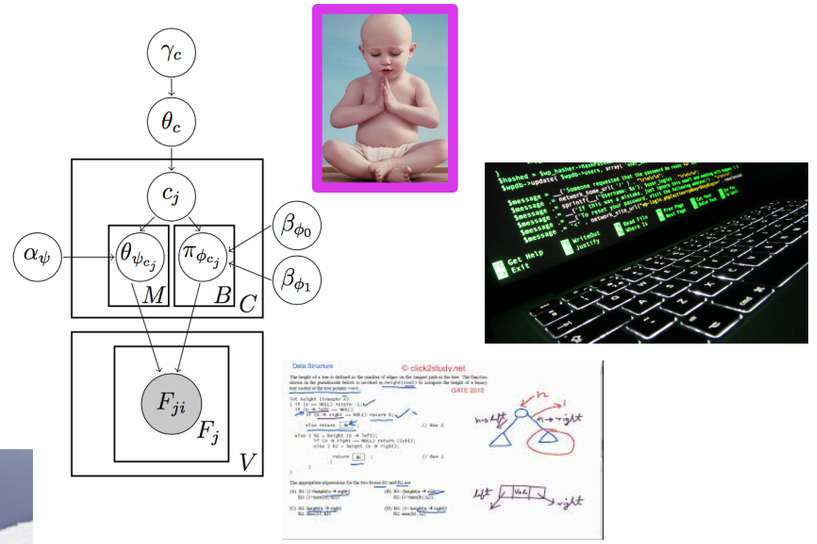
Linguistics 2016

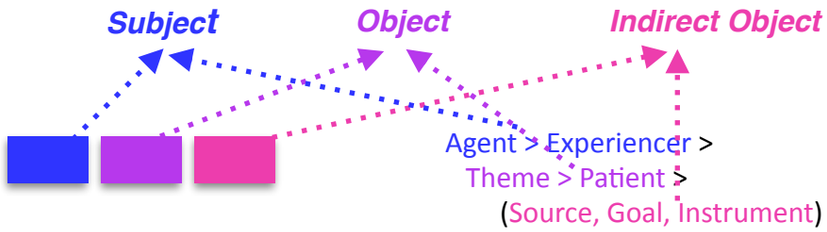
done-to

The ice melted.

The penguin climbed.

doer





Computation of Language Laboratory

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NSF

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Thematic roles & how to use them

One idea about how children could use thematic role information: (r)UTAH.

The (**r**elativized) **U**niformity of **T**heta **A**ssignment **H**ypothesis

UG knowledge

UTAH: Baker 1988, Baker 1997, Dowty 1991, Fillmore 1968, Grimshaw 1990, Jackendoff 1987, Perlmutter & Postal 1984, Speas 1990

Each thematic role maps to a specific syntactic position (grammatical role).

control

She tried to melt the ice.
doer *doer* *done-to*

**It tried that she melted the ice.*
doer *done-to*

The penguin seemed to climb the hill.
doer *done-to*

It seemed that the penguin climbed the hill.
doer *done-to*

raising

Pearl & Sprouse in progress

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Each thematic role maps to a specific syntactic position (grammatical role).

Agent-like = grammatical subject

Agent
Causer
Experiencer
Possessor

("internal cause" = Rappaport-Hovav 1995)

control

She tried to melt the ice.
doer doer done-to

*It tried that she melted the ice.
doer done-to

The penguin seemed to climb the hill.
doer done-to

It seemed that the penguin climbed the hill.
doer done-to

raising

Pearl & Sprouse in progress

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Causer
Experiencer *(*Baker: only when subject)*
Possessor

("internal cause" = Rappaport-Hovav 1995)

control

She tried to melt the ice.
doer
doer
done-to

*It tried that she melted the ice.
doer
done-to

She fears spiders.
Experiencer

Spiders frighten her.
Experiencer

The penguin seemed to climb the hill.
doer
done-to

It seemed that the penguin climbed the hill.
doer
done-to

raising

Pearl & Sprouse in progress

Thematic roles & how to use them

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The (**r**elativized) **U**niformity of **T**heta **A**ssignment **H**ypothesis — UG knowledge

UTAH: Baker 1988, Baker 1997, Dowty 1991, Fillmore 1968, Grimshaw 1990, Jackendoff 1987, Perlmutter & Postal 1984, Speas 1990

Each thematic role maps to a specific syntactic position (grammatical role).

Agent-like = grammatical subject

Patient-like = grammatical object

Patient
Theme
Experiencer
Subject Matter

("external cause")

control

She tried to melt the ice.
doer *doer* *done-to*

**It tried that she melted the ice*
doer *done-to*

The penguin seemed to climb the hill.
doer *done-to*

It seemed that the penguin climbed the hill.
doer *done-to*

raising

Pearl & Sprouse in progress

Thematic roles & how to use them

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The (**r**elativized) **U**niformity of **T**heta **A**ssignment **H**ypothesis

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Each thematic role maps to a specific syntactic position (grammatical role).

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Patient

Theme

Experiencer *(*Baker: only when not subject)*

Subject Matter

("external cause")

She fears spiders.
Experiencer

Spiders frighten her.
Experiencer

control

She tried to melt the ice.
doer ***doer*** ***done-to***

**Baker: only when not subject*

It tried that she melted the ice.
doer ***done-to***

raising

The penguin seemed to climb the hill.
doer ***done-to***

It seemed that the penguin climbed the hill.
doer ***done-to***

Pearl & Sprouse in progress

Thematic roles & how to use them

One idea about how children could use thematic role information: (r)UTAH.

The (relativized) Uniformity of Theta Assignment Hypothesis   UG knowledge

UTAH: Baker 1988, Baker 1997, Dowty 1991, Fillmore 1968, Grimshaw 1990, Jackendoff 1987, Perlmutter & Postal 1984, Speas 1990

Each thematic role maps to a specific syntactic position (grammatical role).

Agent-like = grammatical subject
Patient-like = grammatical object
Goal-like = grammatical indirect object

Location
Source
Goal
Benefactor
Instrument

control

She tried to melt the ice with a blow dryer.
doer / doer — done-to — done-with

*It tried that she melted the ice with a blow dryer.
doer — done-to — done-with

The penguin seemed to climb the hill.
doer — done-to

It seemed that the penguin climbed the hill.
doer — done-to

raising

Pearl & Sprouse in progress

Thematic roles & how to use them

Syntax

She melted **the ice** with **a blow dryer**.

Subject ***Object*** ***Indirect Object***

Mapping to Syntax

UG knowledge

The **U**niformity of **T**heta **A**ssignment **H**ypothesis:

Baker 1988, Baker 1997, Dowty 1991, Fillmore 1968, Grimshaw 1990, Jackendoff 1987, Perlmutter & Postal 1984, Speas 1990

UTAH

Intermediate representations

Thematic roles map to one of three categories.

thematic-roles

(likely derived from lower level conceptual info) =
Agent, Experiencer, Patient, Theme, Goal, Source, Instrument…

Thematic roles & how to use them

One idea about how children could use thematic role information: (r)UTAH.

The (**r**elativized) **U**niformity of **T**heta **A**ssignment **H**ypothesis

UG knowledge

rUTAH: Larson 1988, Larson 1990

Thematic roles are ordered relative to each other, with the highest thematic role mapping to the highest grammatical role (subject > object > indirect object).

control

She tried to melt the ice with a blow dryer.
doer ***doer*** ***done-to*** ***done-with***

**It tried that she melted the ice with a blow dryer.*
doer ***done-to*** ***done-with***

The penguin seemed to climb the hill.
doer ***done-to***

It seemed that the penguin climbed the hill.
doer ***done-to***

raising

Pearl & Sprouse in progress

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Basic intuition:
doer (Agent-like) >
done-to (Patient-like) >
done-for/with (Goal-like)

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An example implementation:
Agent > Causer > Experiencer > Possessor >
Subject Matter > Causee > Theme > Patient >
(Location, Source, Goal, Benefactor, Instrument)

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doer *doer* *done-to* *done-with*

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Note: You don't need to have every role relatively ranked. If some are unranked with respect to each other, the order in which they get mapped to grammatical positions doesn't matter.

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doer *done-to*

It seemed that the penguin climbed the hill.
doer *done-to*

raising

Pearl & Sprouse in progress

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This relative ranking can help deal with certain situations, like those involving Experiencers.

She fears spiders.
Experiencer ***Subject Matter***

Experiencer **>** ***Subject Matter***

Subject ***Object***

Spiders frighten her.
Causer ***Experiencer***

Causer **>** ***Experiencer***

Subject ***Object***

Pearl & Sprouse in progress