Integrating conceptual and structural cues: Theories for syntactic acquisition

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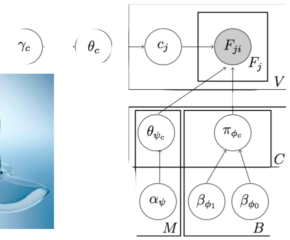


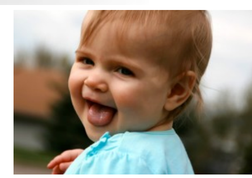
done-to

The ice melted.

The penguin climbed.

doer

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



Sept 17, 2016: SynLinks 2016

University of Connecticut, Storrs

Syntactic acquisition

While syntactic acquisition is (by definition) about learning linguistic structure, children use information of different kinds in order to accomplish it.

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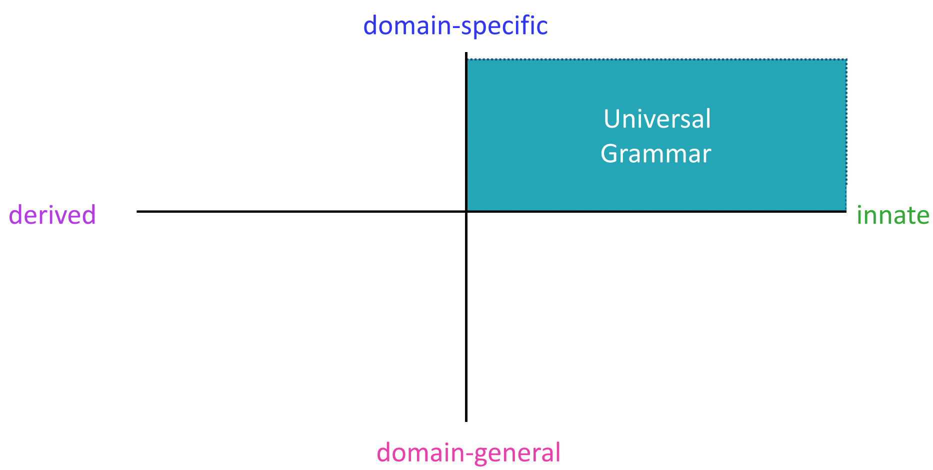
prior knowledge (Universal Grammar or otherwise)



Syntactic acquisition

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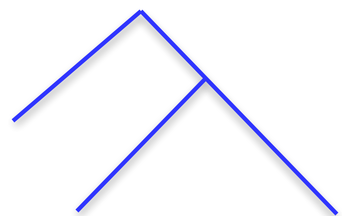
prior knowledge (Universal Grammar or otherwise)

syntactic cues

NP __ NP



Syntactic acquisition

While syntactic acquisition is (by definition) about learning linguistic structure, children use information of different kinds in order to accomplish it.

prior knowledge (Universal Grammar or otherwise)

syntactic cues

conceptual cues

+animate

-animate

Syntactic acquisition

While syntactic acquisition is (by definition) about learning linguistic structure, children use information of different kinds in order to accomplish it.

prior knowledge (Universal Grammar or otherwise)

syntactic cues

conceptual cues

semantic-syntactic cues

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

Subject	Object	Indirect Object
Agent	*Patient*	*Instrument*

Syntactic acquisition

Given this, it seems useful to consider learning theories that leverage these different information types.

prior knowledge (Universal Grammar or otherwise)

syntactic cues

conceptual cues

semantic-syntactic cues

It's even more useful to be concrete, so let's look at a specific case study:

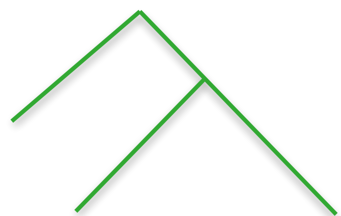
The Linking Problem (where event participants appear syntactically)

Today's plan

Linking Problem overview & some theories for handling it

done-to
The ice melted.
The penguin climbed.
doer

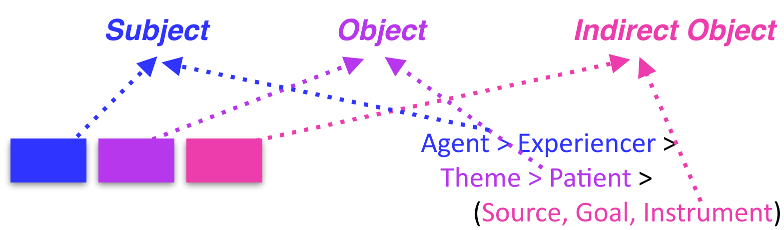
Theory evaluation with computational modeling: A primer



The ice melted.
What happened?
The ground's shaking.

The penguin climbed.
Who laughed?
She's winking.

Theory evaluation: The Linking Problem



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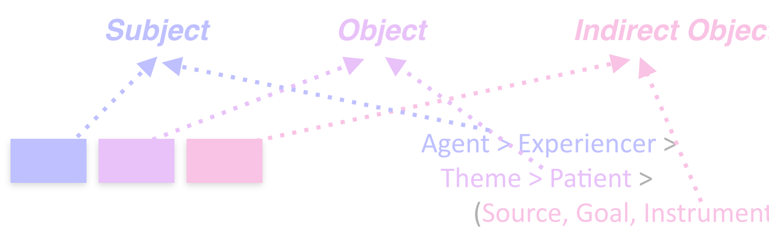


The Linking Problem

- **Why**? About how conceptual information maps to syntactic structure, and we have some proposals for how to capture the empirical facts (e.g., (r)UTAH, Case Theory)

Pearl & Sprouse in progress

The Linking Problem

- **Why**? About how conceptual information maps to syntactic structure, and we have some proposals for how to capture the empirical facts (e.g., (r)UTAH, Case Theory)

- **What**? Predicates such as verbs allow a variety of syntactic options for where and how their arguments appear and each predicate has certain linguistic patterns of behavior.

She melted the ice.
doer done-to

The ice melted.
done-to

The ice was melted.
done-to

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

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

The penguin climbed the hill.
doer done-to

The penguin climbed.
doer

The hill was climbed.
done-to

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

The Linking Problem: Acquisition

One way to figure out how a new predicate will behave is to determine what kind of predicate it is (i.e., what predicate category it belongs to) with the idea that predicates in the same category behave similarly.

unaccusative

She melted the ice.
doer done-to

The ice melted.
done-to

The ice was melted.
done-to

control

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

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

The penguin climbed the hill.
doer done-to

The penguin climbed.
doer

The hill was climbed.
done-to

unergative

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

The Linking Problem: Acquisition

One way to figure out how a new predicate will behave is to determine what kind of predicate it is (i.e., what predicate category it belongs to) with the idea that predicates in the same category behave similarly.

The river froze.

? ? ? ?

unaccusative

She melted the ice.
doer *done-to*

The ice melted.
done-to

The ice was melted.
done-to

control

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

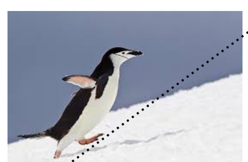
**It tried that she melted the ice.*
doer *done-to*

The penguin climbed the hill.
doer *done-to*

The penguin climbed.
doer

The hill was climbed.
done-to

unergative



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

The Linking Problem: Acquisition

One way to figure out how a new predicate will behave is to determine what kind of predicate it is (i.e., what predicate category it belongs to) with the idea that predicates in the same category behave similarly.

crack
break
close
freeze

unaccusative

The river froze.

She melted the ice.
doer *done-to*

The ice melted.
done-to

The ice was melted.
done-to

control

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

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

The penguin climbed the hill.
doer *done-to*

The penguin climbed.
doer

The hill was climbed.
done-to

unergative

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

The Linking Problem: Acquisition

Knowledge transfer: Once you figure out how one predicate in the category behaves, you know something about how all the predicates in the category behave. This helps you predict how the conceptual arguments will surface syntactically for that new predicate.

break
crack
close
freeze
freeze

The ice froze.
done-to

unaccusative

She melted the ice.
doer done-to

The ice melted.
done-to

The ice was melted.
done-to

The penguin climbed the hill.
doer done-to

The penguin climbed.
doer

The hill was climbed.
done-to

unergative

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

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doer done-to

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

raising

Pearl & Sprouse in progress

The Linking Problem: Acquisition

Important foundation: Making useful predicate categories. What cues are available to do this?

break crack close freeze freeze

The ice froze.
done-to

unaccusative

She melted the ice.
doer *done-to*

The ice melted.
done-to

The ice was melted.
done-to

control

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

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

raising

Pearl & Sprouse in progress

The Linking Problem: Available cues

One type of cue: Syntactic cues

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

Relevant cue: syntactic structure

May be shallow "syntactic skeleton" (Gutman et al. 2015) that includes tense and aspect information or not.

unaccusative

She melted the ice.
doer *done-to*

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done-to

The penguin climbed the hill.
doer *done-to*

The penguin climbed.
doer

The hill was climbed.
done-to

unergative

Pearl & Sprouse in progress

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The penguin climbed the hill.
doer *done-to*

The penguin climbed.
doer

The hill was climbed.
done-to

unergative

May be shallow "syntactic skeleton" (Gutman et al. 2015) that includes tense and aspect information or not.

+ some available tense and aspect information

She melted the ice —> $NP\ V_{past}\ NP$

The ice melted —> $NP\ V_{past}$

The ice was melted —> $NP\ V_{past\_participle}$

The ice was melting —> $NP\ V_{progressive\_participle}$

Pearl & Sprouse in progress

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She melted the ice.
doer *done-to*

The ice melted.
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The ice was melted.
done-to

+ some available tense and aspect information

She melted the ice —> NP V_{past} NP

The ice melted —> NP V_{past}

The ice was melted —> NP $V_{past\_participle}$

The ice was melting —> NP $V_{progressive\_participle}$

The penguin climbed the hill.
doer *done-to*

The penguin climbed.
doer

The hill was climbed.
done-to

unergative

ignore available tense and aspect information

She melted the ice —> NP V NP

The ice melted —> NP V

The ice was melted —> NP V

The ice was melting —> NP V

Pearl & Sprouse in progress

The Linking Problem: Available cues

One type of cue: Syntactic cues

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Relevant cue: syntactic structure

Why include tense and aspect information? Tenny's (1987 1994) Aspectual Interface Hypothesis suggests that aspect may be a useful cue to verb class (telic = unaccusative, atelic = unergative). Tense and aspect affect telicity and are sometimes easily observable in the morphology.

unaccusative

She melted the ice.
doer *done-to*

The ice melted.
done-to

The ice was melted.
done-to

+ some available tense and aspect information

She melted the ice —> NP V_{past} NP

The ice melted —> NP V_{past}

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The penguin climbed the hill.
doer *done-to*

The penguin climbed.
doer

The hill was climbed.
done-to

unergative

ignore available tense and aspect information

She melted the ice —> NP V NP

The ice melted —> NP V

The ice was melted —> NP V

The ice was melting —> NP V

Pearl & Sprouse in progress

The Linking Problem: Available cues

Another type of cue: Conceptual cues (non-linguistic)

Example: Animacy is useful for distinguishing predicate classes like raising vs. control verbs, and psych-object-experiencer verbs. Young children have been shown to use this cue in experimental studies (Becker 2009, Kirby 2009, Kirby 2010, Becker 2014, Becker 2015, Hartshorne et al. 2015).

-animate

control

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

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

+animate

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

The Linking Problem: Available cues

Another type of cue: Conceptual cues (non-linguistic)

Example: Thematic roles (e.g., *Agent, Patient*) that indicate participant roles in an event are salient to very young children [<10 months: Gordon 2003; 6 months: Hamlin, Wynn, & Bloom 2007, Hamlin, Wynn, Bloom, & Mahajan 2011].

-animate

control

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

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

+animate

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: semantic-syntactic information

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

Subject *Object* *Indirect Object*

How do we get from here to here?

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

Thematic roles & how to use them: semantic-syntactic information

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: semantic-syntactic information

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

Subject *Object* *Indirect Object*

Mapping to Syntax

UG knowledge

The (relativized) Uniformity of Theta Assignment Hypothesis:
Larson 1988, Larson 1990

UTAH

rUTAH

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

Intermediate representations

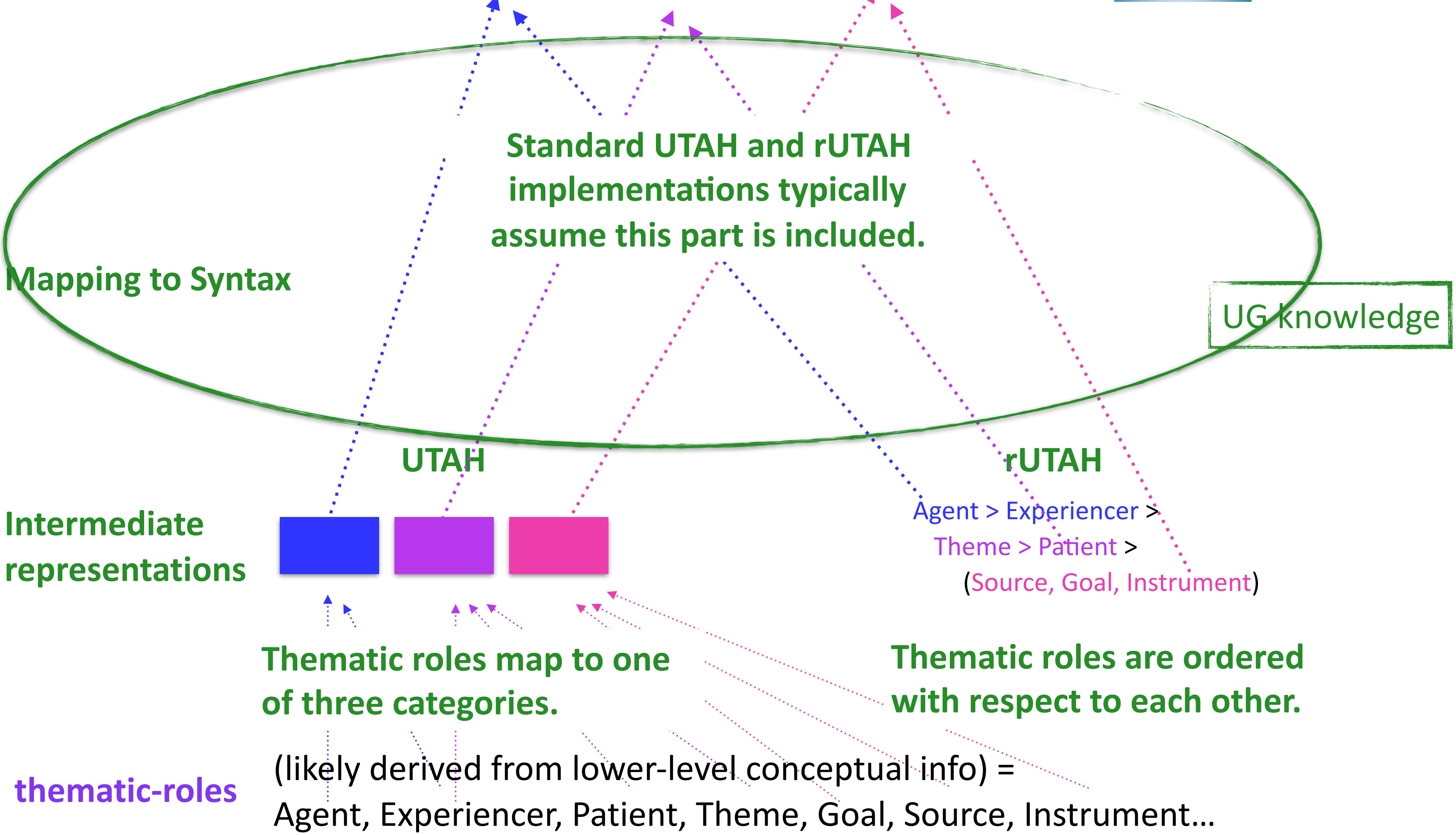
Thematic roles map to one of three categories.

Thematic roles are ordered with respect to each other.

thematic-roles

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

Thematic roles & how to use them: semantic-syntactic information



Thematic roles & how to use them: semantic-syntactic information

If children expect the mapping to hold, it may be especially salient to them when it doesn't. Such instances would be accounted for by movement.

UG knowledge

UTAH

rUTAH

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

+exp-mapping

Pearl & Sprouse in progress

Thematic roles & how to use them: semantic-syntactic information

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UG knowledge

UTAH

rUTAH

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

+exp-mapping

The ice was melted by the girl.

done-to — **Subject**

doer — **Indirect Object**

Pearl & Sprouse in progress

Thematic roles & how to use them: semantic-syntactic information

If children expect the mapping to hold, it may be especially salient to them when it doesn't. Such instances would be accounted for by movement.

UG knowledge

UTAH

rUTAH

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

+exp-mapping

Unexpected by (r)UTAH

The ice was melted by the girl.

done-to **Subject** — *doer* **Indirect Object**

Pearl & Sprouse in progress

Thematic roles & how to use them: semantic-syntactic information

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

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

But we could also look at implementations that don't assume this mapping is fixed a priori.
This would be a weaker version of standard (r)UTAH implementations.

Mapping to Syntax

UG knowledge

UTAH **rUTAH**

Intermediate representations

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

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

Thematic roles & how to use them: semantic-syntactic information

Alternatively, children could simply track the distributions of where intermediate representation roles appear with respect to grammatical positions. (No absolute expectation yet that the mapping will hold. This is something children would have to infer through exposure to the input.)

UG knowledge

UTAH

rUTAH

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

-exp-mapping

The ice was melted by the girl.
done-to *doer*
Subject **Indirect Object**

Pearl & Sprouse in progress

Thematic roles & how to use them: semantic-syntactic information

Alternatively, children could simply track the distributions of where intermediate representation roles appear with respect to grammatical positions. (No absolute expectation yet that the mapping will hold. This is something children would have to infer through exposure to the input.)

melt:
Patient-like/2nd highest—Subject
Agent-like/highest—Indirect Object

-exp-mapping

UG knowledge

UTAH

rUTAH

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

The ice was melted by the girl.

done-to **Subject**

doer **Indirect Object**

Pearl & Sprouse in progress

Thematic roles & how to use them: semantic-syntactic information

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

Subject *Object* *Indirect Object*

+exp-mapping:
movement is salient because mapping to syntax is fixed

-exp-mapping:
syntax mapping distributions are tracked

Mapping to Syntax

UG knowledge

UTAH

rUTAH

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

Intermediate representations

Thematic roles map to one of three categories.

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

Thematic roles & how to use them: semantic-syntactic information

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

Subject *Object* *Indirect Object*

+exp-mapping: movement is salient because mapping to syntax is fixed ← **Choice 2** → **-exp-mapping:** syntax mapping distributions are tracked

Mapping to Syntax

UG knowledge

UTAH ← **Choice 1** → **rUTAH**

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

Intermediate representations

Thematic roles map to one of three categories.

Thematic roles are ordered with respect to each other.

thematic-roles

(likely derived from lower-level conceptual info) =
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Potential learning strategies

UG knowledge options

UTAH, -exp-mapping

UTAH, +exp-mapping

rUTAH, -exp-mapping

rUTAH, +exp-mapping

Pearl & Sprouse in progress

Potential learning strategies

UG knowledge options

UTAH, -exp-mapping

UTAH, +exp-mapping

rUTAH, -exp-mapping

rUTAH, +exp-mapping

Additional learner information: Syntactic options (+/- tense & aspect in the surface morphology)

+ some available tense and aspect information

She melted the ice —> NP V_{past} NP

The ice melted —> NP V_{past}

The ice was melted —> NP $V_{past\_participle}$

The ice was melting —> NP $V_{progressive\_participle}$

ignore available tense and aspect information

She melted the ice —> NP V NP

The ice melted —> NP V

The ice was melted —> NP V

The ice was melting —> NP V

Pearl & Sprouse in progress

Potential learning strategies

UG knowledge options

UTAH, -exp-mapping
UTAH, +exp-mapping
rUTAH, -exp-mapping
rUTAH, +exp-mapping

+ some available tense and aspect information
The ice was melted —> NP $V_{past\_participle}$

8 different learning strategy variants

UTAH, -exp-mapping
UTAH, +exp-mapping
rUTAH, -exp-mapping
rUTAH, +exp-mapping

ignore available tense and aspect information
The ice was melted —> NP V

Pearl & Sprouse in progress

Potential learning strategies

UG knowledge options
UTAH, -exp-mapping
UTAH, +exp-mapping
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rUTAH, +exp-mapping

+ some available tense and aspect information
The ice was melted —> NP $V_{past\_participle}$

8 different learning strategy variants

UTAH, -exp-mapping
UTAH, +exp-mapping
rUTAH, -exp-mapping
rUTAH, +exp-mapping

ignore available tense and aspect information
The ice was melted —> NP V

All learners are sensitive to the animacy of NPs.

-animate

+animate

Pearl & Sprouse in progress

Learning strategy options

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

Subject *Object* *Indirect Object*

-tense/aspect info ← **Choice 3** → **+tense/aspect info**

+exp-mapping: movement is salient because mapping to syntax is fixed ← **Choice 2** → **-exp-mapping:** syntax mapping distributions are tracked

Mapping to Syntax

UG knowledge

UTAH ← **Choice 1** → **rUTAH**

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

Intermediate representations

Thematic roles map to one of three categories.

Thematic roles are ordered with respect to each other.

thematic-roles

(likely derived from lower-level conceptual info) =
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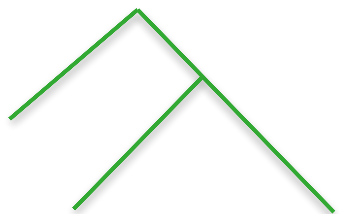
Today's plan

Linking Problem overview & some theories for handling it

done-to
The ice melted.
The penguin climbed.
doer

Theory evaluation with computational modeling: A primer



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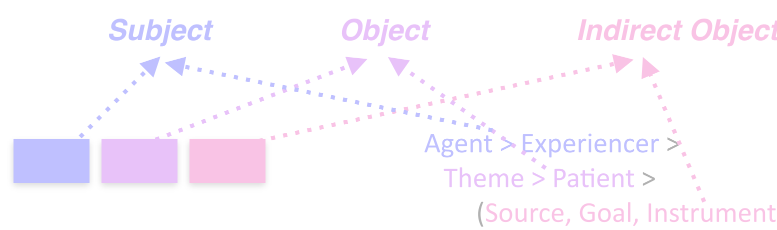
Who laughed?
She's winking.

Theory evaluation: The Linking Problem



Learning theory proposals: Generation & evaluation

How to generate a learning theory proposal:

Characterize the learning problem precisely and identify a potential solution.

8 different learning strategy variants

Learning theory proposals: Generation & evaluation

How to generate a learning theory proposal:

Characterize the learning problem precisely and identify a potential solution.

Benefit of computational modeling:
We can make sure the learning problem is characterized precisely enough to implement. It's not always obvious what pieces are missing until you try to build a model of the learning process.
(Pearl 2014, Pearl & Sprouse 2015)

Learning theory proposals: Generation & evaluation

How to generate a learning theory proposal:

Characterize the learning problem precisely and identify a potential solution.

How to evaluate a learning theory proposal:

See if it's successful when embedded in a model of the acquisition process for that learning problem.

Learning theory proposals: Generation & evaluation

How to generate a learning theory proposal:

Characterize the learning problem precisely and identify a potential solution.

How to evaluate a learning theory proposal:

See if it's successful when embedded in a model of the acquisition process for that learning problem.

Recently, in computational modeling, we've seen the integration of rich hypothesis spaces with probabilistic/statistical learning mechanisms (Sakas & Fodor 2001, Yang 2004, Pearl 2011, Dillon et al. 2013, Pearl & Sprouse 2013, Pearl et al. 2014, Pearl & Mis 2016, among many others).

Learning theory proposals: Generation & evaluation

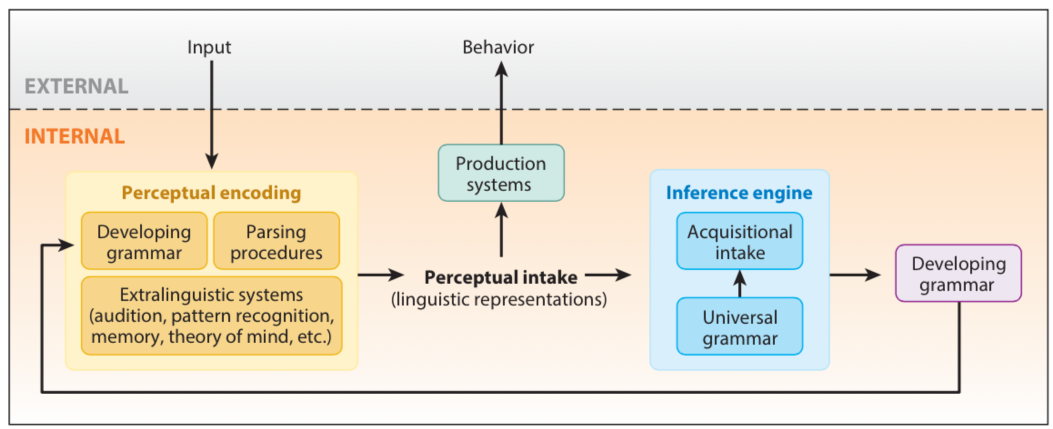
How to generate a learning theory proposal:

Characterize the learning problem precisely and identify a potential solution.

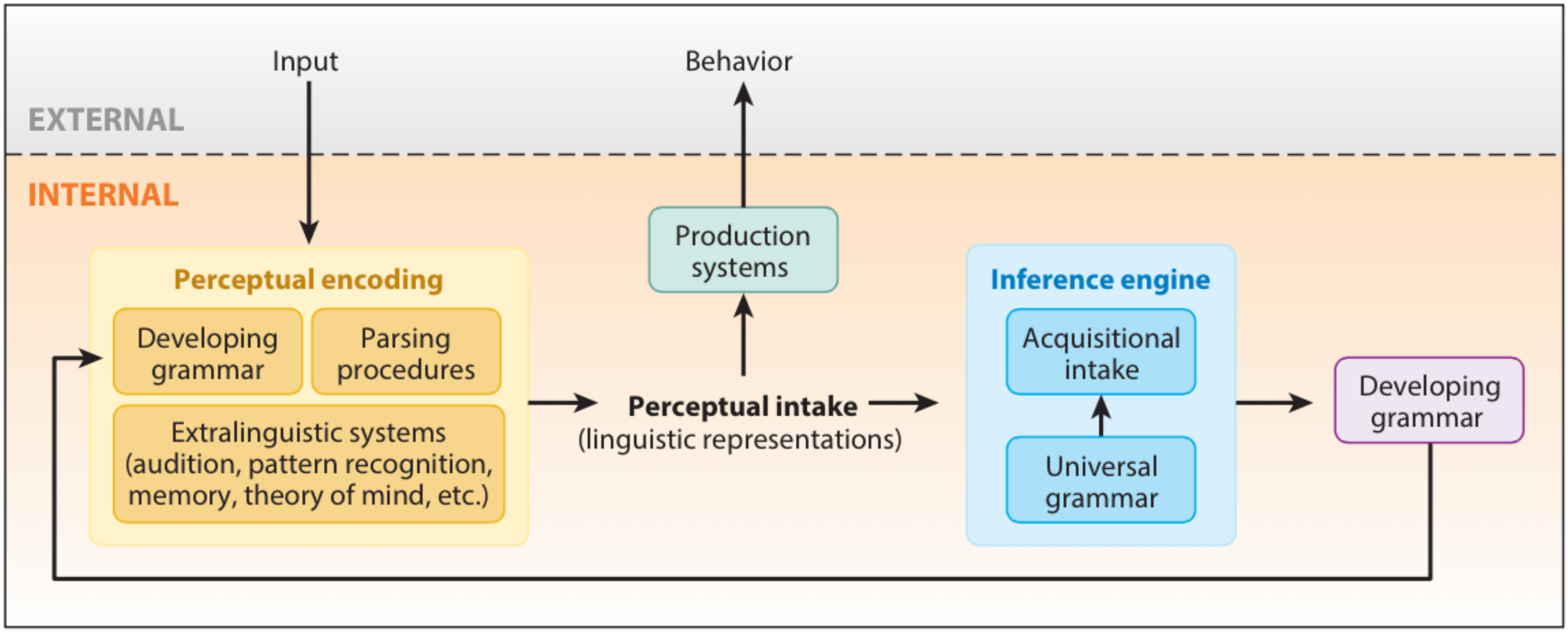
How to evaluate a learning theory proposal:

See if it's successful when embedded in a model of the acquisition process for that learning problem.

We've also seen the development of more sophisticated acquisition frameworks that highlight the precise role of different components (Lidz & Gagliardi 2015, Omaki & Lidz 2015).



The Lidz & Gagliardi (2015) acquisition framework



Lidz & Gagliardi 2015

Learning theory proposals: Generation & evaluation

How to generate a learning theory proposal:

Characterize the learning problem precisely and identify a potential solution.

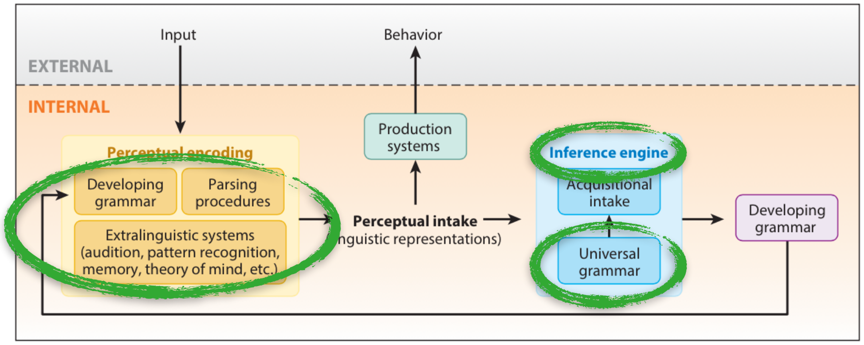
How to evaluate a learning theory proposal:

See if it's successful when embedded in a model of the acquisition process for that learning problem.

This computational modeling approach helps us refine our theories about both the knowledge representation the learning theory relies on and the acquisition process that uses that representation.

Characterizing learning problems

Initial state:



Lidz & Gagliardi 2015

Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

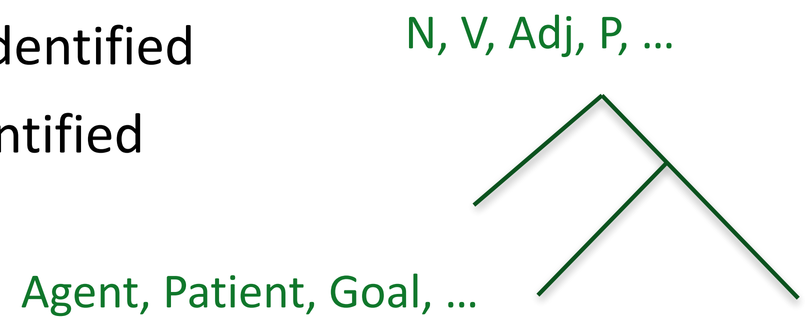
Initial state:

- initial knowledge state

ex: syntactic categories exist and can be identified

ex: phrase structure exists and can be identified

ex: participant roles can be identified



Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

Initial state:

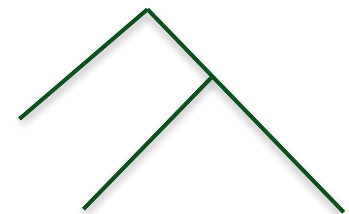
- initial knowledge state

ex: syntactic categories exist and can be identified

ex: phrase structure exists and can be identified

ex: participant roles can be identified

N, V, Adj, P, …



Agent, Patient, Goal, …

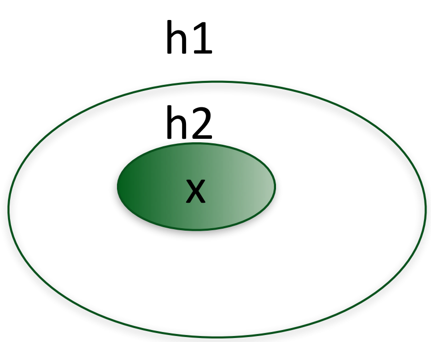
- learning biases & capabilities

ex: frequency information can be tracked

ex: distributional information can be leveraged

The ice melted.
What happened?
The ground's shaking.

The penguin climbed.
Who laughed?
She's winking.

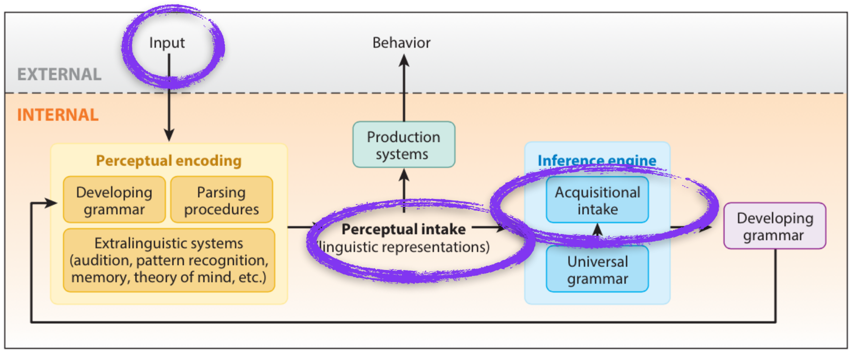


Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

Initial state: initial knowledge state + learning biases & capabilities

Data intake:



Lidz & Gagliardi 2015

Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

Initial state: initial knowledge state + learning biases & capabilities

Data intake:

- input + encoding + acquisitional intake = data perceived as relevant for learning

(Fodor 1998, Lidz & Gagliardi 2015)

ex: syntactic and conceptual data for learning syntactic knowledge that links with conceptual knowledge

[defined by knowledge & biases/capabilities in the initial state]

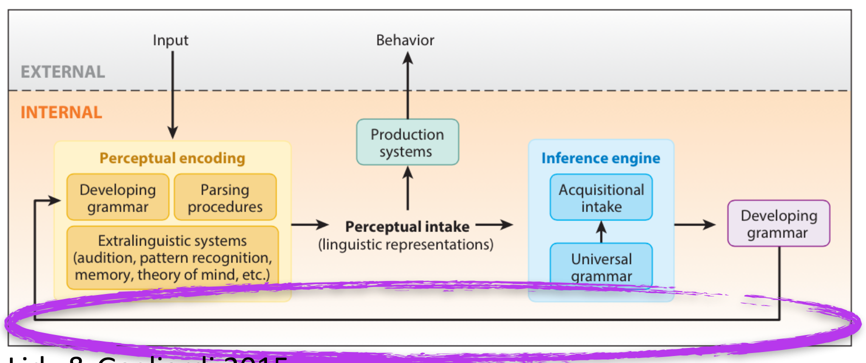
Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

Initial state: initial knowledge state + learning biases & capabilities

Data intake: data perceived as relevant for learning

Learning period:



Lidz & Gagliardi 2015

Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

Initial state: initial knowledge state + learning biases & capabilities

Data intake: data perceived as relevant for learning

Learning period:

- how long children have to reach the target knowledge state (when inference & iteration happen)

ex: 3 years, ~1,000,000 data points

ex: 4 months, ~36,500 data points

Pearl & Sprouse 2015, Pearl & Mis 2016

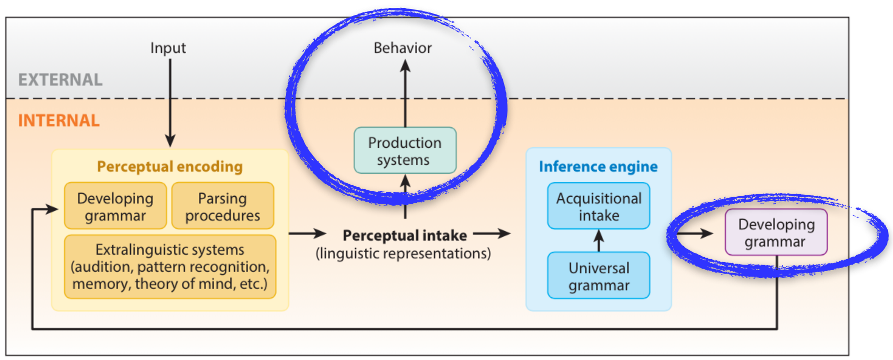
Characterizing learning problems

Initial state: initial knowledge state + learning biases & capabilities

Data intake: data perceived as relevant for learning

Learning period: how long children have to learn

Target state:



Lidz & Gagliardi 2015

Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

Initial state: initial knowledge state + learning biases & capabilities

Data intake: data perceived as relevant for learning

Learning period: how long children have to learn

Target state:

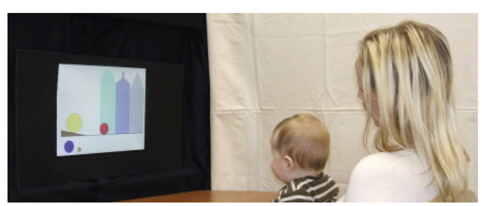
- the knowledge children are trying to attain (as indicated by their behavior)

ex: *done-to*

The ice melted.

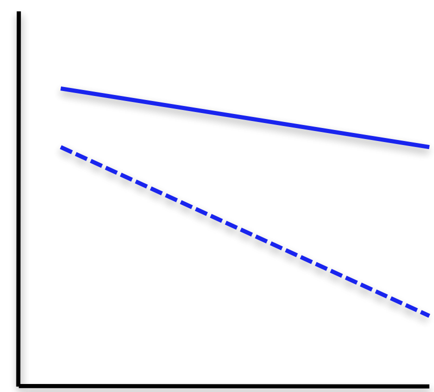
The penguin climbed.

doer



looking time preferences

z-score rating



Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

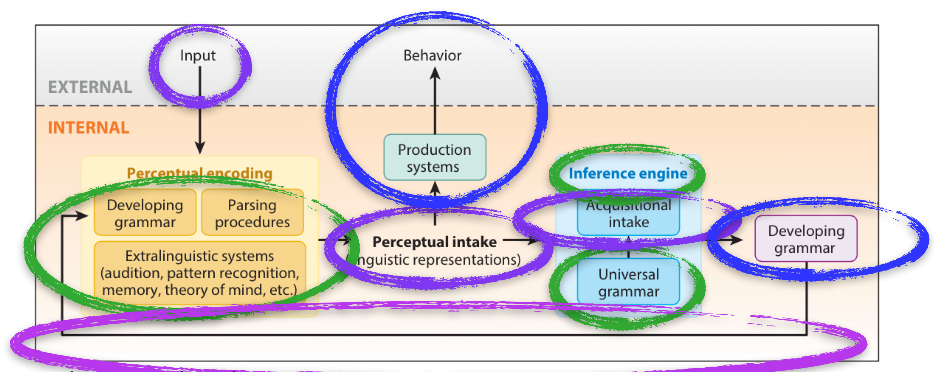
Initial state: initial knowledge state + learning biases & capabilities

Data intake: data perceived as relevant for learning

Learning period: how long children have to learn

Target state: the knowledge children must attain

Once we have all these pieces specified, we should be able to implement an informative model of the learning process.



Lidz & Gagliardi 2015

Pearl & Sprouse 2015, Pearl & Mis 2016

Informing theories of knowledge & learning

When we identify a successful learning strategy via modeling, this is an existence proof that children could solve that learning problem using the knowledge, learning biases, and capabilities comprising that strategy.

This identifies useful learning strategy components, which include both the knowledge components (= **theories of representation**) and the biases & capabilities that must exist for that knowledge to be successfully deployed during acquisition (= **theories of the learning process**).

Knowledge 1
Knowledge 2
Bias 1
Bias 2
Bias 3
Capability 1

…

Today's plan

Linking Problem overview & some theories for handling it

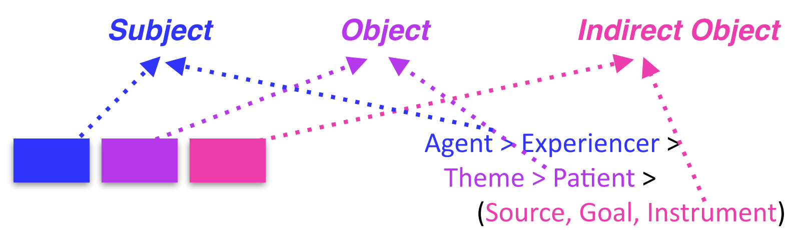
done-to
The ice melted.
The penguin climbed.
doer

Theory evaluation with computational modeling: A primer

The ice melted.
What happened?
The ground's shaking.

The penguin climbed.
Who laughed?
She's winking.

Theory evaluation: The Linking Problem



Potential learning strategies revisited

UG knowledge options
UTAH, -exp-mapping
UTAH, +exp-mapping
rUTAH, -exp-mapping
rUTAH, +exp-mapping

+ some available tense and aspect information
The ice was melted —> NP $V_{past\_participle}$

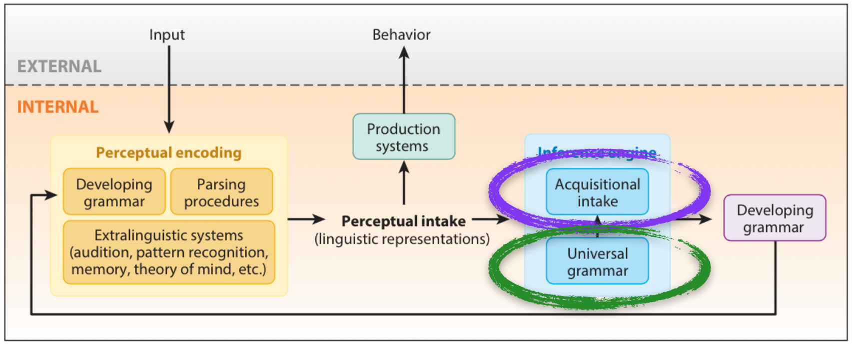
8 different learning strategy variants

UTAH, -exp-mapping
UTAH, +exp-mapping
rUTAH, -exp-mapping
rUTAH, +exp-mapping

ignore available tense and aspect information
The ice was melted —> NP V

-animate

+animate



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Initial state

The ability to identify and extract all relevant information reliably (syntactic + conceptual + semantic-syntactic cues) + sufficient statistical learning abilities to track and use this information.

UG knowledge options

UTAH, -exp-mapping
UTAH, +exp-mapping
rUTAH, -exp-mapping
rUTAH, +exp-mapping

+ some available tense and aspect information

The ice was melted —> NP $V_{past\_participle}$

8 different learning strategy variants

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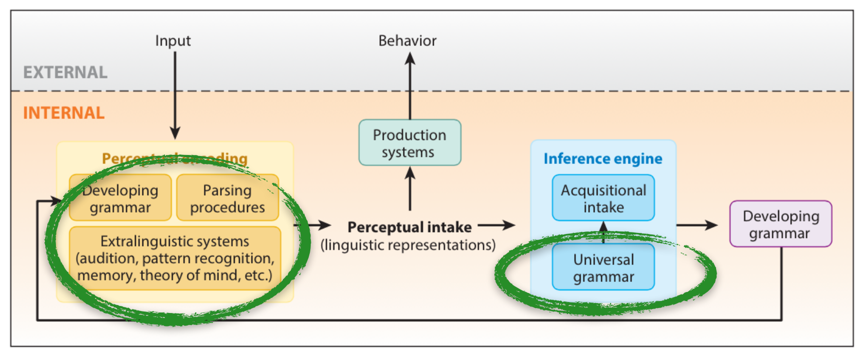
rUTAH, +exp-mapping

ignore available tense and aspect information

The ice was melted —> NP V

-animate

+animate



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Initial state

The ability to identify and extract all relevant information reliably (syntactic + conceptual + semantic-syntactic cues) + sufficient statistical learning abilities to track and use this information.

UG knowledge options

UTAH, -exp-mapping

UTAH, +exp-mapping

rUTAH, -exp-mapping

rUTAH, +exp-mapping

+ some available tense and aspect information

The ice was melted —> NP $V_{past\_participle}$

8 different variants, which all cause different **acquisitional intakes**

UTAH, -exp-mapping

UTAH, +exp-mapping

rUTAH, -exp-mapping

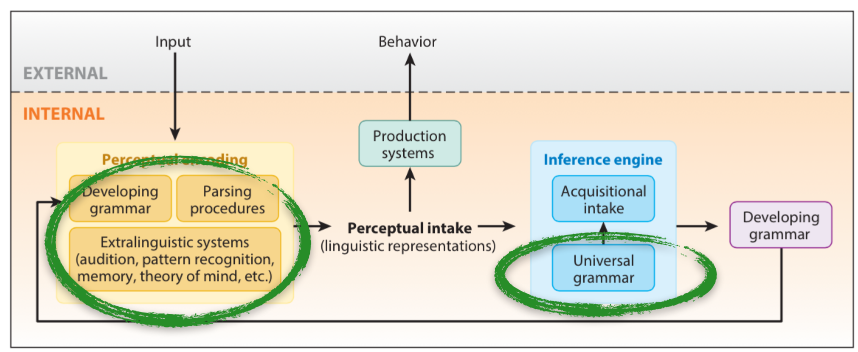
rUTAH, +exp-mapping

ignore available tense and aspect information

The ice was melted —> NP V

-animate

+animate



Lidz & Gagliardi 2015

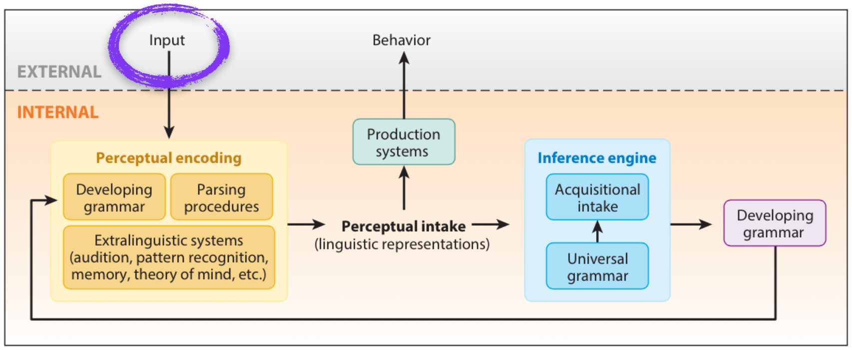
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

“it’s falling off”

Input



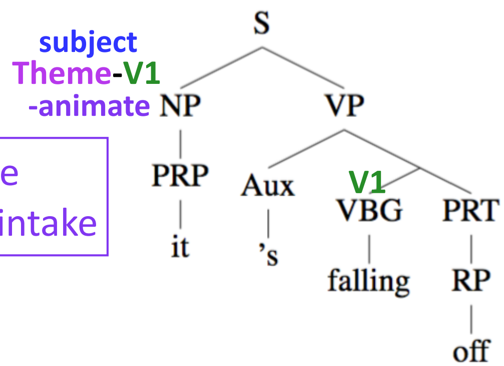
Lidz & Gagliardi 2015

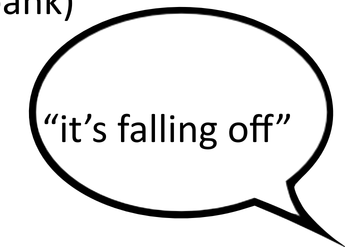
Pearl & Sprouse in progress

Acquisitional intake options

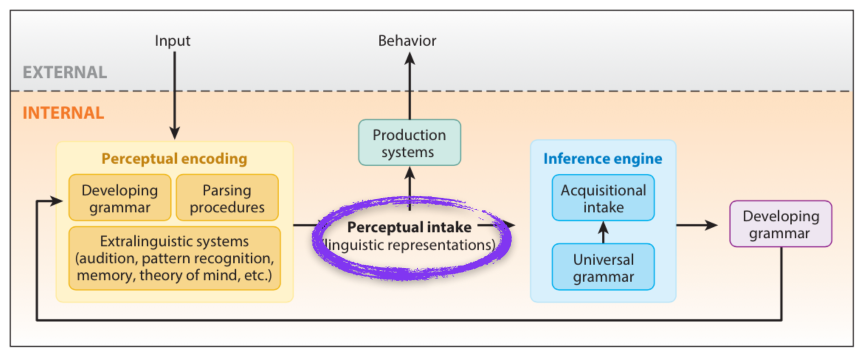
(from Brown-Eve corpus from CHILDES Treebank)

Possible perceptual intake





Input



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

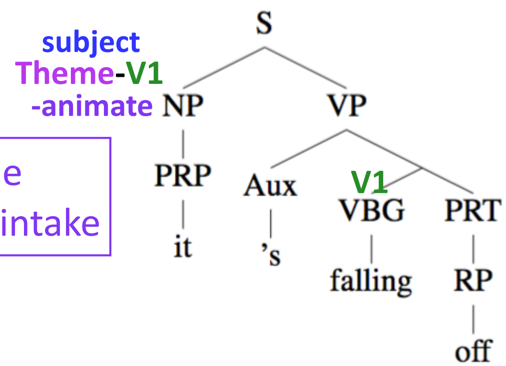
Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

"it's falling off"

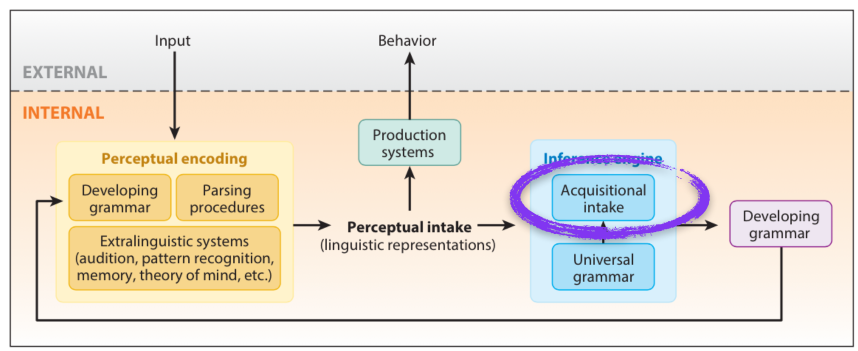
Input

Possible perceptual intake



Acquisitional intake

(1) UTAH, -exp-mapping,+some available tense and aspect information



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

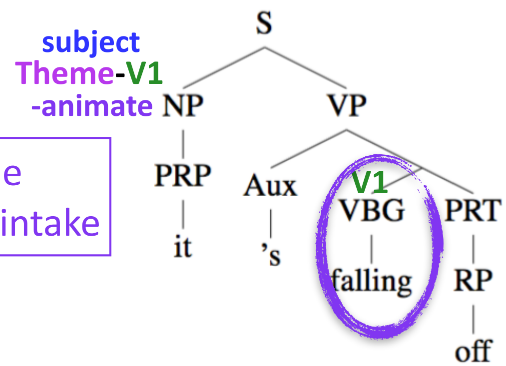
Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

“it’s falling off”

Input

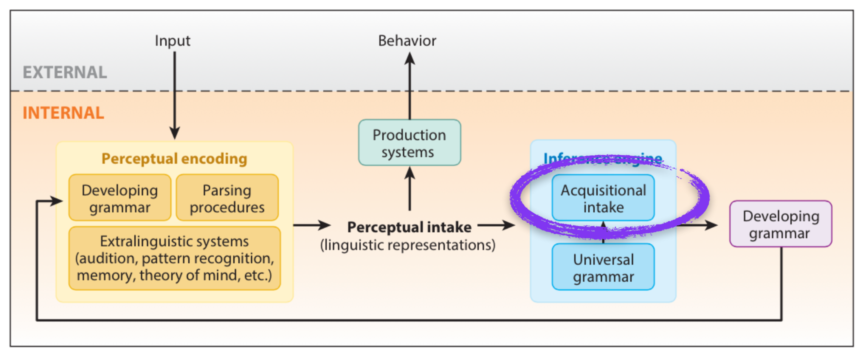
Possible perceptual intake



Acquisitional intake

(1) UTAH, -exp-mapping,+some available tense and aspect information

FALL

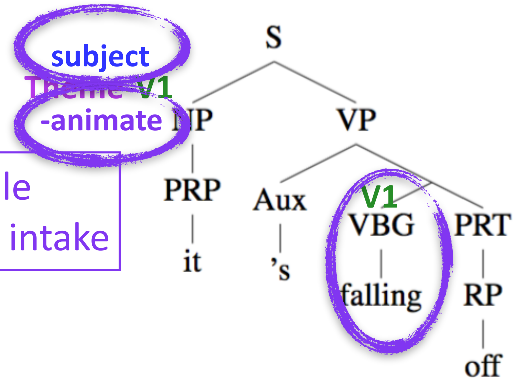


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



Possible perceptual intake

"it's falling off"

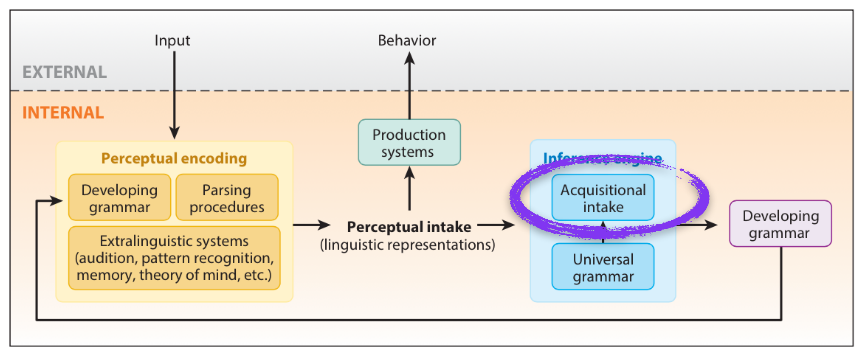
Input

Acquisitional intake

(1) UTAH, -exp-mapping,+some available tense and aspect information

FALL

-animate subject: 1

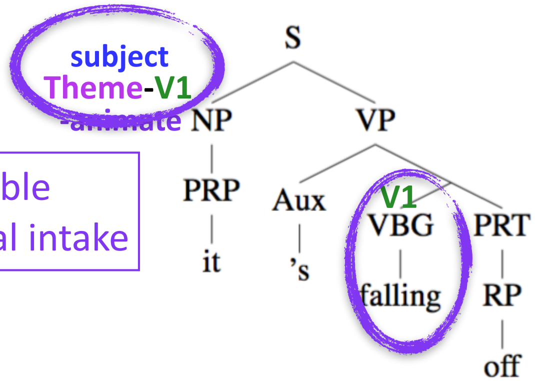


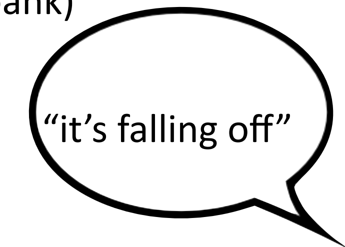
Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)





Possible perceptual intake

Input

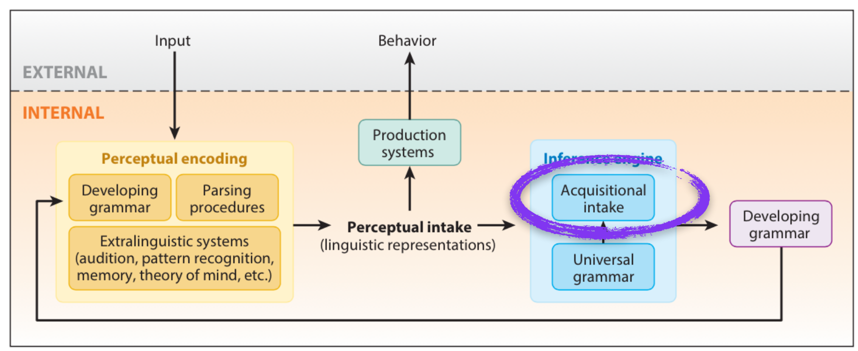
Acquisitional intake

(1) UTAH, -exp-mapping,+some available tense and aspect information

FALL

-animate subject: 1

Patient-like as subject: 1

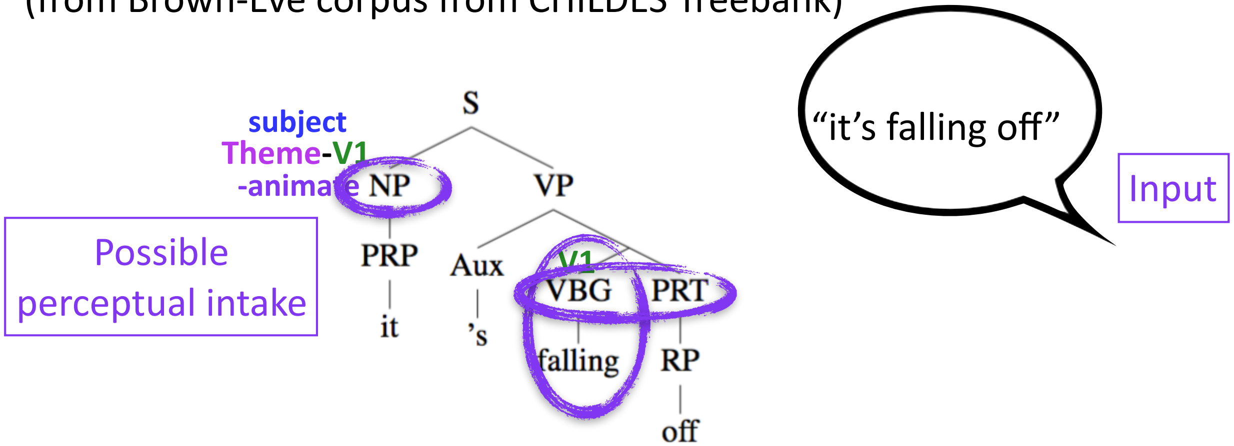


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



Acquisitional intake

(1) UTAH, -exp-mapping,+some available tense and aspect information

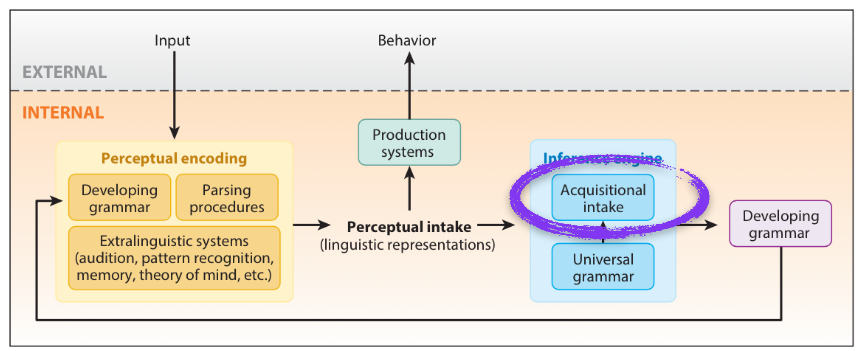
FALL

-animate subject: 1

Patient-like as subject: 1

NP $V_{present\_participle}$ PRT

Note: CHILDES Treebank syntactic encoding captures these distinctions:
(i) present (VBP) vs. past tense (VBD)
(ii) present participle (VBG) vs. past participle (VBN)
(iii) non-finite usage (VB)

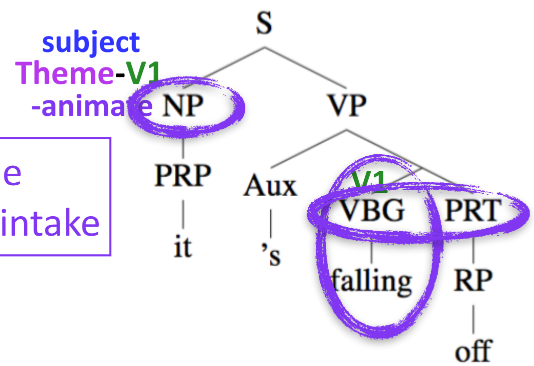


Lidz & Gagliardi 2015

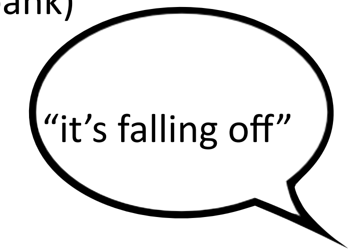
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



Possible perceptual intake



Input

Acquisitional intake

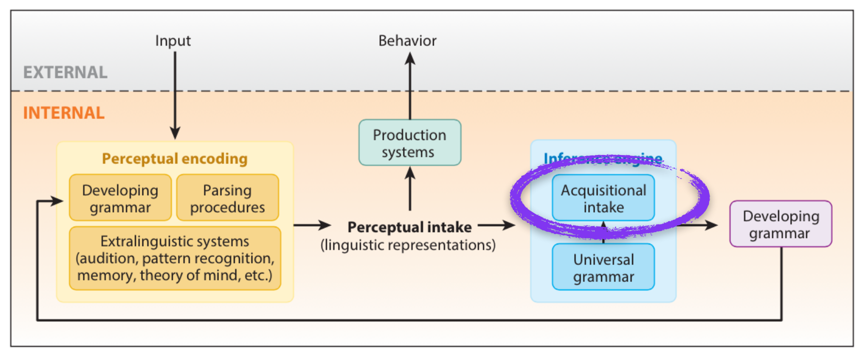
(2) UTAH, -exp-mapping,-some available tense and aspect information

FALL

-animate subject: 1

Patient-like as subject: 1

NP V PRT



Lidz & Gagliardi 2015

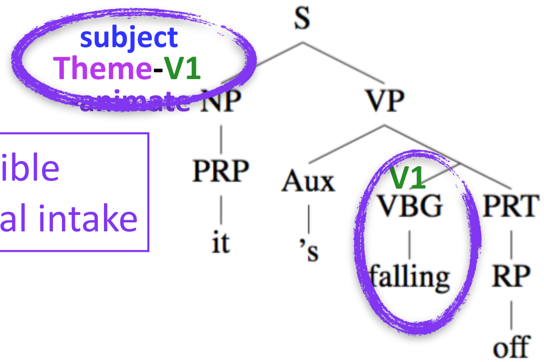
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

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

Possible perceptual intake



"it's falling off"

Input

Acquisitional intake

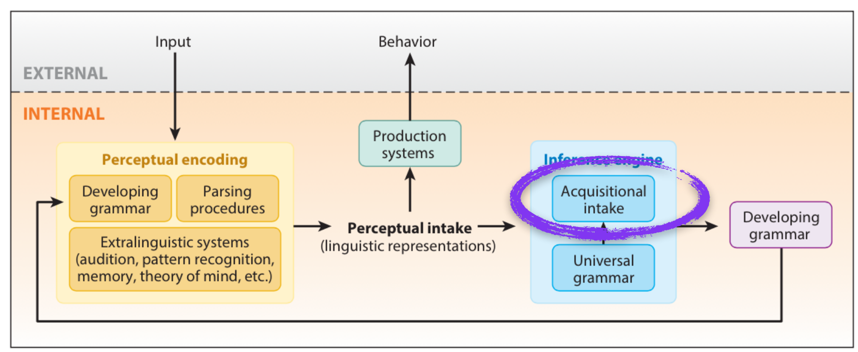
(3) UTAH, +exp-mapping,-some available tense and aspect information

FALL

-animate subject: 1

+movement: 1

NP V PRT

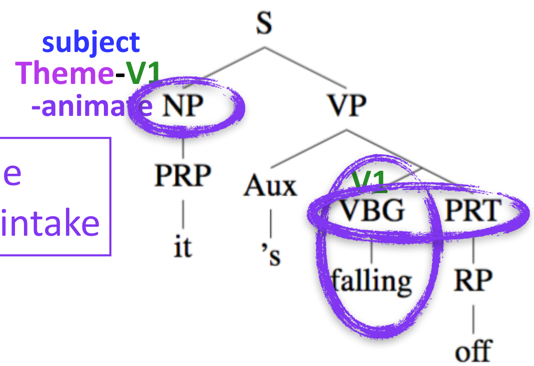


Lidz & Gagliardi 2015

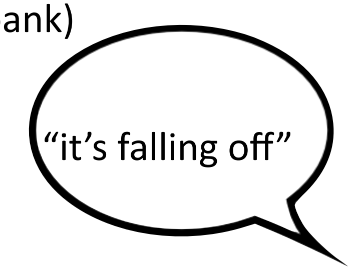
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



Possible perceptual intake



Input

Acquisitional intake

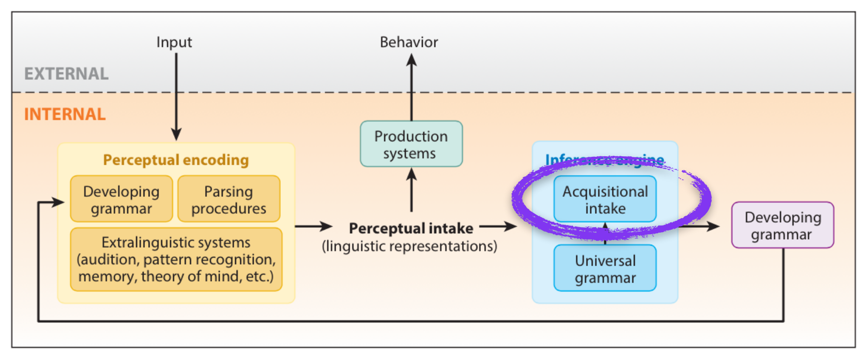
(4) UTAH, +exp-mapping,+some available tense and aspect information

FALL

-animate subject: 1

+movement: 1

NP $V_{present\_participle}$ PRT



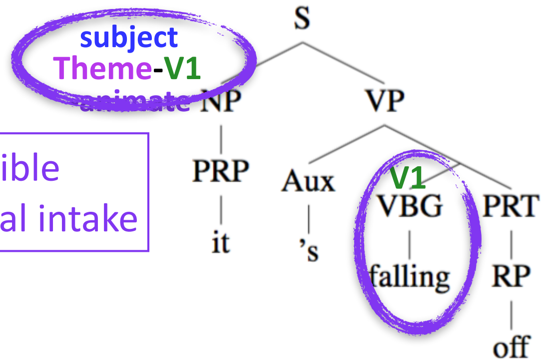
Lidz & Gagliardi 2015

Pearl & Sprouse in progress

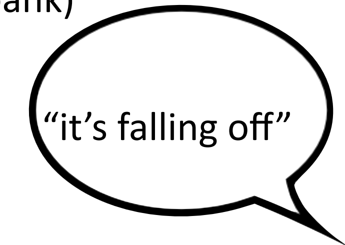
Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

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



Possible perceptual intake



Input

Acquisitional intake

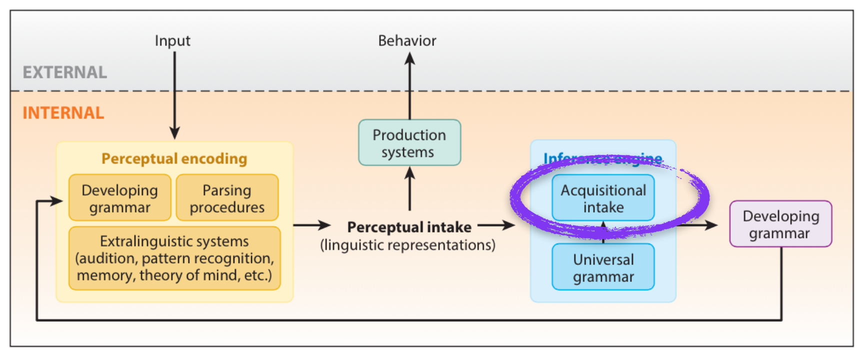
(5) rUTAH, +exp-mapping,+some available tense and aspect information

FALL

-animate subject: 1

+movement: 0

NP $V_{present\_participle}$ PRT



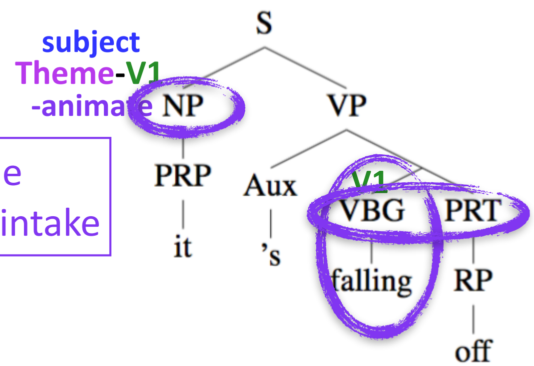
Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

Possible perceptual intake



"it's falling off"

Input

Acquisitional intake

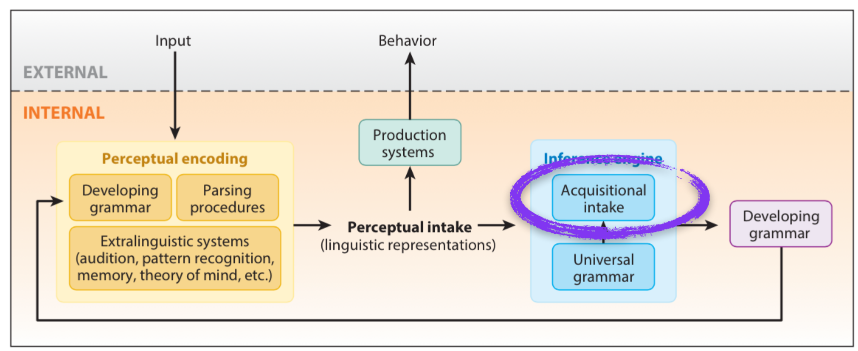
(6) rUTAH, +exp-mapping,-some available tense and aspect information

FALL

-animate subject: 1

+movement: 0

NP V PRT



Lidz & Gagliardi 2015

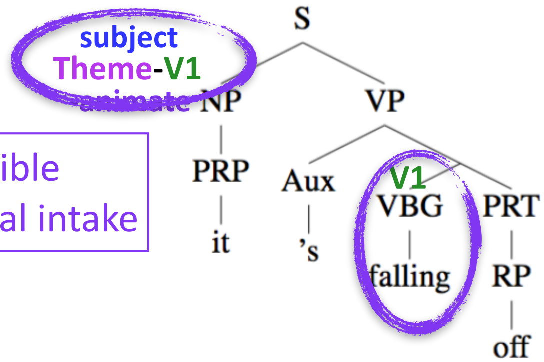
Pearl & Sprouse in progress

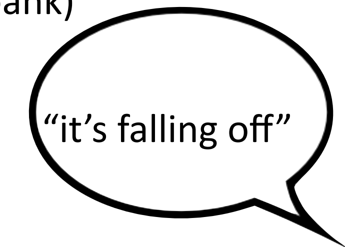
Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

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

Possible perceptual intake





Input

Acquisitional intake

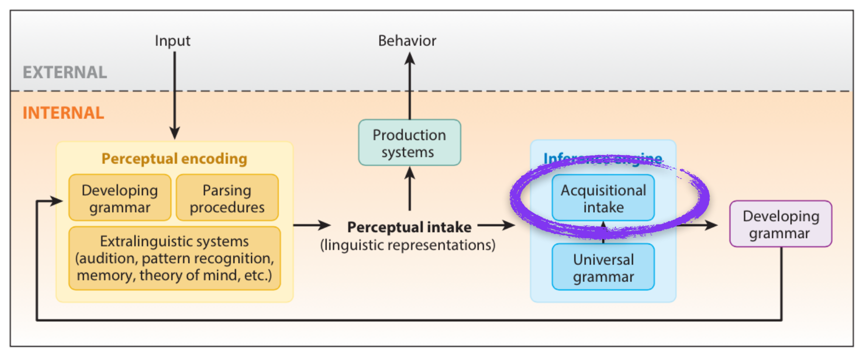
(7) rUTAH, -exp-mapping,-some available tense and aspect information

FALL

-animate subject: 1

Highest role as subject: 1

NP V PRT

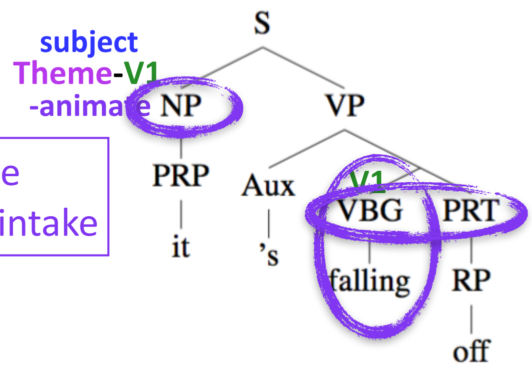


Lidz & Gagliardi 2015

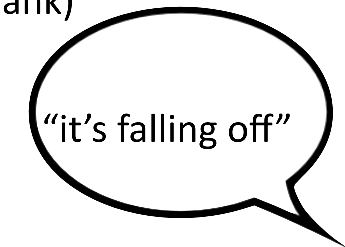
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



Possible perceptual intake



Input

Acquisitional intake

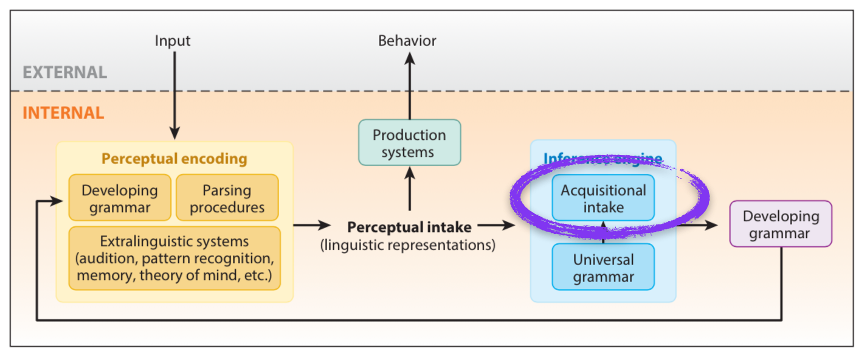
(8) rUTAH, -exp-mapping,+some available tense and aspect information

FALL

-animate subject: 1

Highest role as subject: 1

NP $V_{present\_participle}$ PRT



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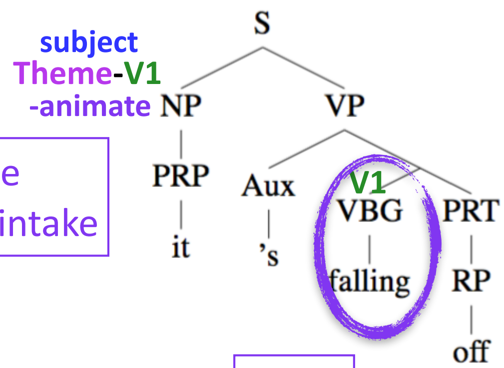
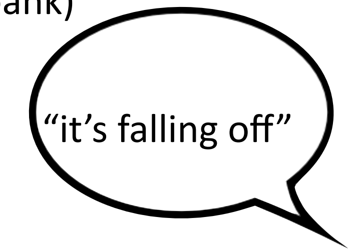
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)





Input

Possible perceptual intake

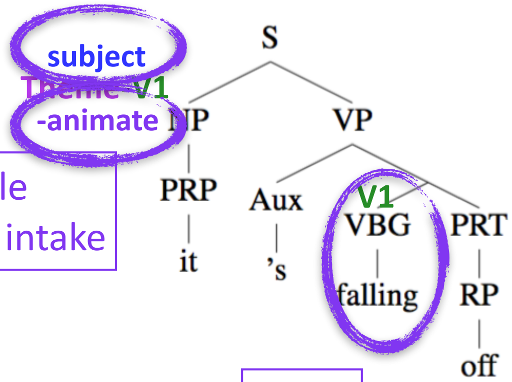
FALL

Comparison: 8 learners

Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



“it’s falling off”

Input

Possible perceptual intake

FALL

Comparison: 8 learners

animacy

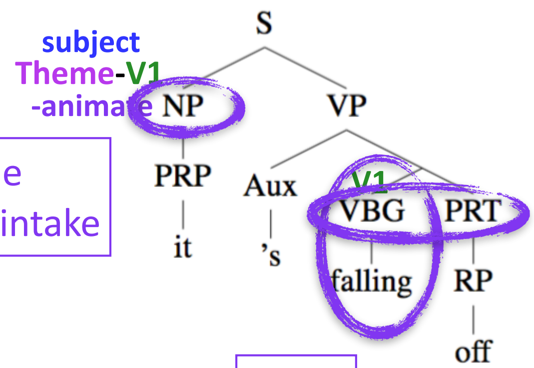
-animate subject: 1

All 8 learners

Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



"it's falling off"

Input

Possible perceptual intake

FALL

Comparison: 8 learners

animacy

-animate subject: 1

+tense/aspect

NP $V_{present\_participle}$ PRT

4 learners

-tense/aspect

NP V PRT

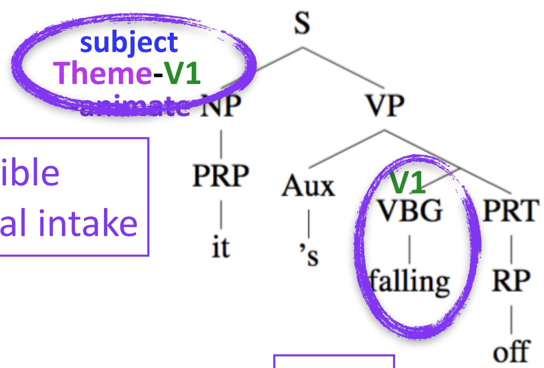
4 learners

Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

Possible perceptual intake



"it's falling off"

Input

Comparison: 8 learners

FALL

animacy

-animate subject: 1

+tense/aspect

NP $V_{present\_participle}$ PRT

-tense/aspect

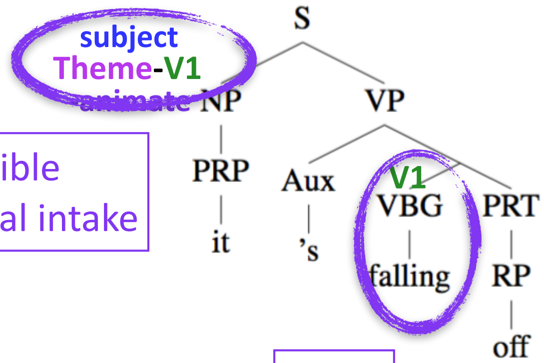
NP V PRT

UTAH	*rUTAH*	*UTAH*	*rUTAH*
Patient-like as *subject*	*Highest* as *subject*	*Patient-like* as *subject*	*Highest* as *subject*
2 learners	**2 learners**	**2 learners**	**2 learners**

Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



"it's falling off"

Input

Possible perceptual intake

FALL

Comparison: 8 learners

animacy

-animate subject: 1

+tense/aspect

NP $V_{present\_participle}$ PRT

-tense/aspect

NP V PRT

UTAH — *Patient-like* as *subject*
- *+exp-mapping*: +movement: 1 — **1 learner**
- *-exp-mapping*: Patient-like as subject: 1 — **1 learner**

rUTAH — *Highest* as *subject*
- *+exp-mapping*: +movement: 0 — **1 learner**
- *-exp-mapping*: Highest as subject: 1 — **1 learner**

UTAH — *Patient-like* as *subject*
- *+exp-mapping*: +movement: 1 — **1 learner**
- *-exp-mapping*: Patient-like as subject: 1 — **1 learner**

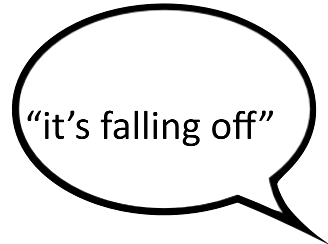
rUTAH — *Highest* as *subject*
- *+exp-mapping*: +movement: 0 — **1 learner**
- *-exp-mapping*: Highest as subject: 1 — **1 learner**

Pearl & Sprouse in progress

Acquisitional intake: Input data

Brown-Eve+Valian

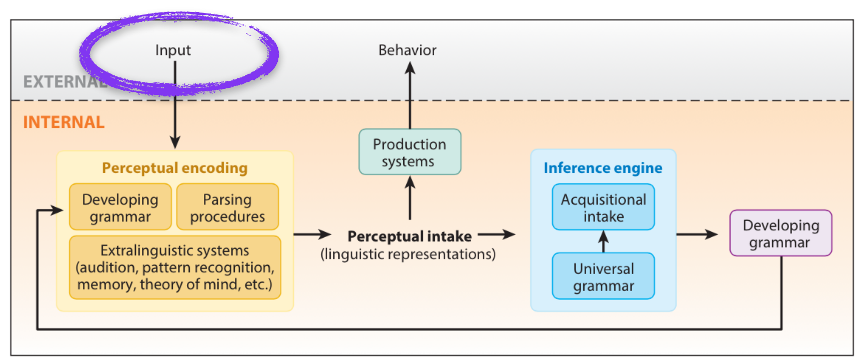
Data come from the Brown-Eve corpus (Brown 1973) and the Valian corpus (Valian 1991), with syntactic & thematic annotations provided by the CHILDES Treebank (Pearl & Sprouse 2013).



Input

This corpus (Brown-Eve+Valian) contains speech directed at 22 children between the ages of 18 and 32 months.

There are ~40,000 utterances total, comprised of ~193,000 word tokens. Of the 553 verb lexical items that appear, 239 occur 5 or more times.



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Acquisitional intake: Input data

Brown-Eve+Valian

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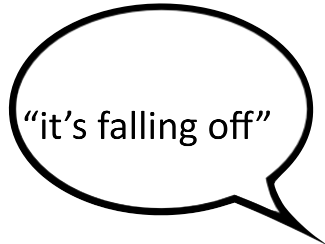
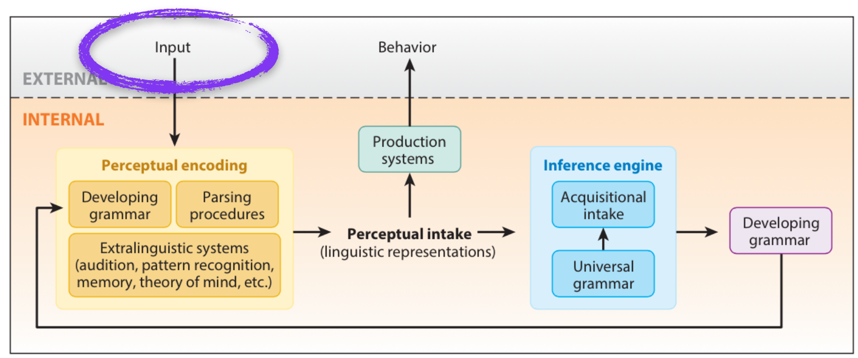


Input

This corpus (Brown-Eve+Valian) contains speech directed at 22 children between the ages of 18 and 32 months.

There are ~40,000 utterances total, comprised of ~193,000 word tokens. Of the 553 verb lexical items that appear, 239 occur 5 or more times.

Focus on learning the predicate categories for these for now.
Intuition: Frequent enough to be useful to distributionally learn from.



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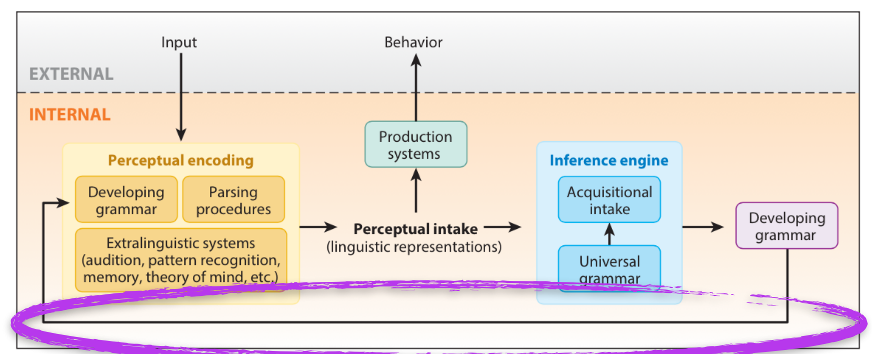
Pearl & Sprouse in progress

Learning period

Basic question: Is it possible for the child to use the acquisitional intake to achieve the target knowledge/behavior in the amount of time children typically get to do it, given the incremental nature of learning and children's cognitive constraints?



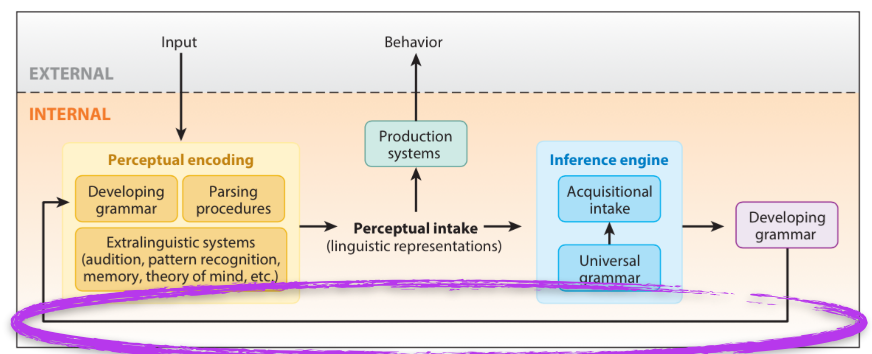
Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning period

Basic question: Is it possible for the child to use the acquisitional intake to achieve the target knowledge/behavior in the amount of time children typically get to do it, given the incremental nature of learning and children's cognitive constraints?

However, before we try to answer this, there's an even more basic question that's often worth asking.



Lidz & Gagliardi 2015

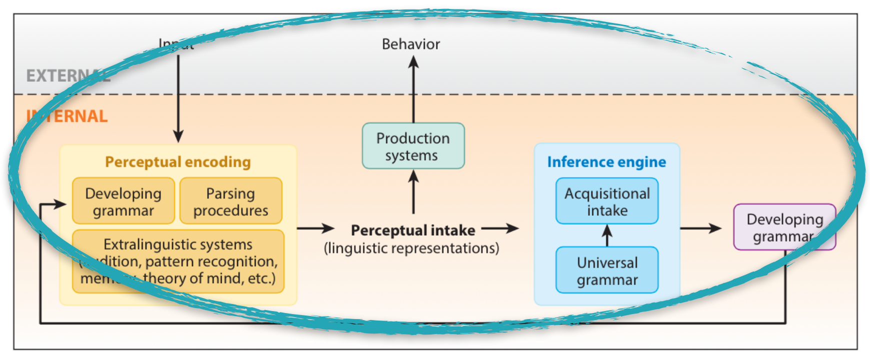
Pearl & Sprouse in progress

Learning period

Even more

Basic question: Is it possible for the child to use the acquisitional intake to achieve the target knowledge/behavior? in the amount of time children typically get to do it, given the incremental nature of learning and children's cognitive constraints?

However, before we try to answer this, there's an even more basic question that's often worth asking.



Lidz & Gagliardi 2015

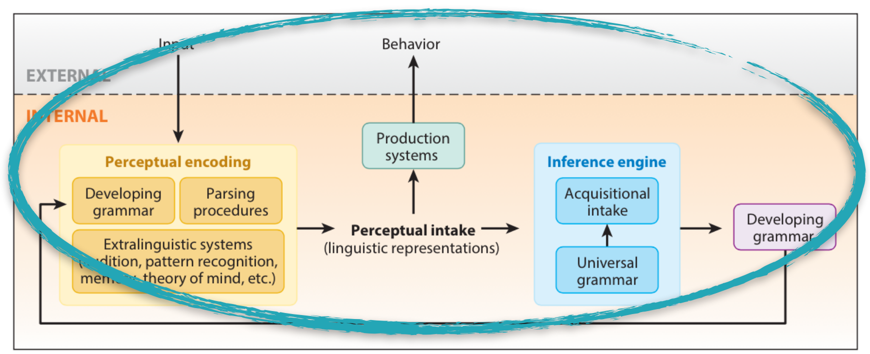
Pearl & Sprouse in progress

Learning period

Even more

Basic question: Is it possible for the child to use the acquisitional intake to achieve the target knowledge/behavior? in the amount of time children typically get to do it, given the incremental nature of learning and children's cognitive constraints?

This is the goal of learnability approaches (often posed at the 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



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning period

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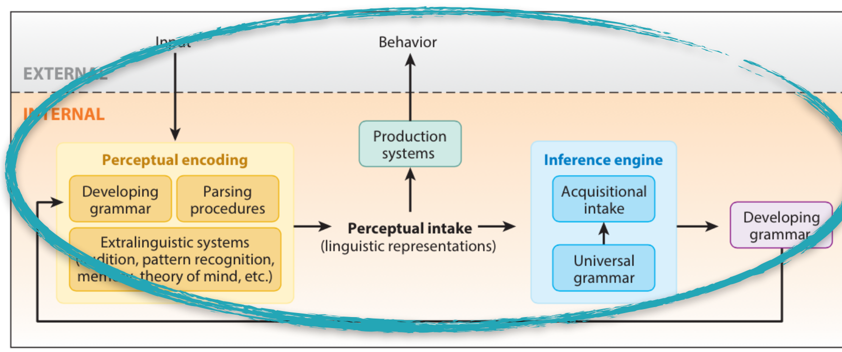
This kind of analysis is very helpful for determining if this implementation of the acquisition task is the right one. In particular, if children are sensitive to this information in the perceptual intake, is that enough to yield the target knowledge/behavior? Are these useful learning assumptions for children to have to create the acquisitional intake? Are these useful representations?



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning period

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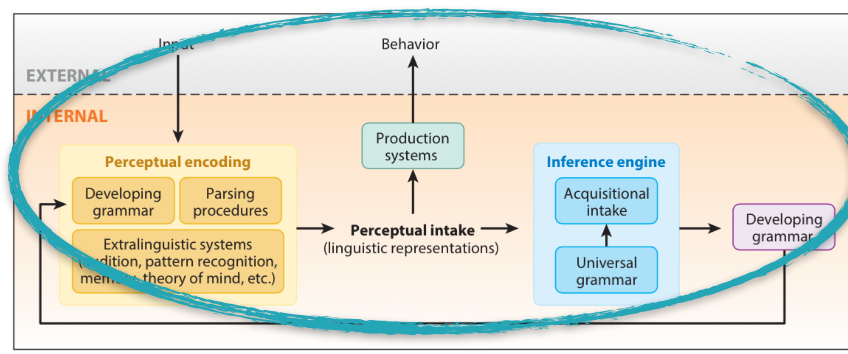
This is typically implemented as an ideal learner model, which isn't concerned with the cognitive limitations and incremental learning restrictions children have.

(That is, useful for children is different from useable by children in real life.)



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Pearl & Sprouse in progress

Learning period

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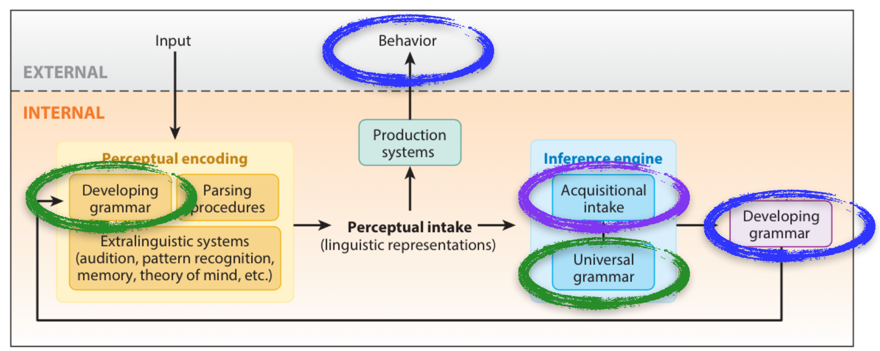
So, for an ideal learner, learning period considerations aren't as important as considerations about the initial state, data intake, and target knowledge/behavior.



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Pearl & Sprouse in progress

Learning period

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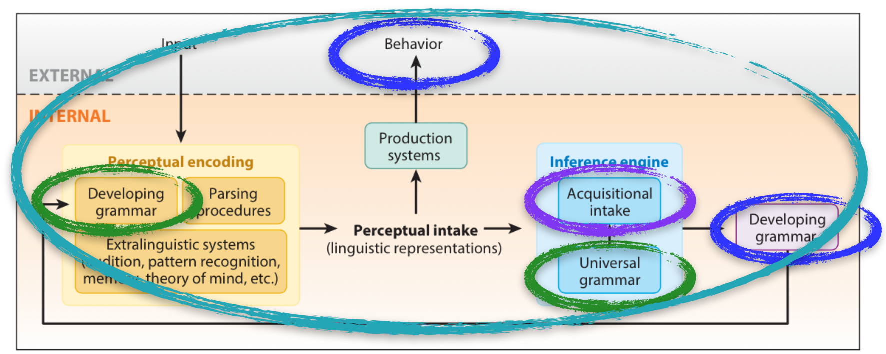
Practical note: Doing a computational analysis is often a really good idea to make sure we've got the right conceptualization of the acquisition task (see Pearl 2011 for the trouble you can get into when you don't do this first).



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

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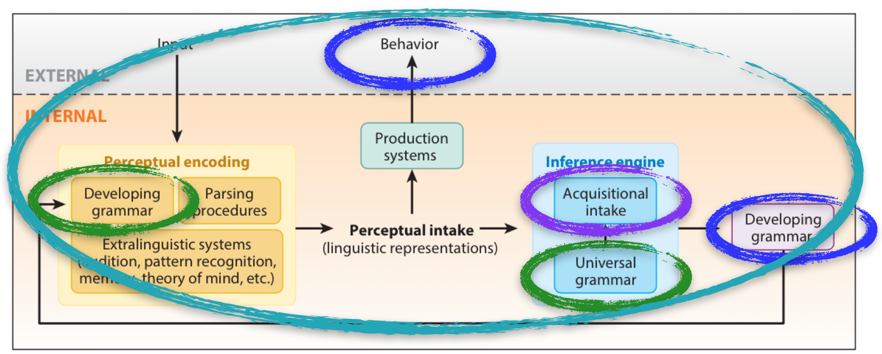
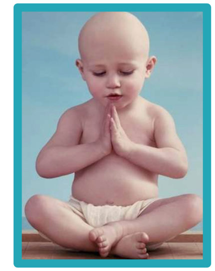
So, that's why we're going to start with a computational-level model of the acquisition process.

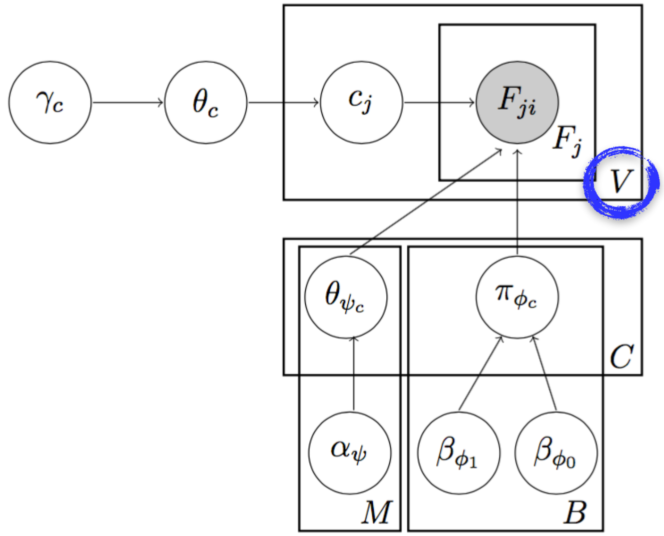


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

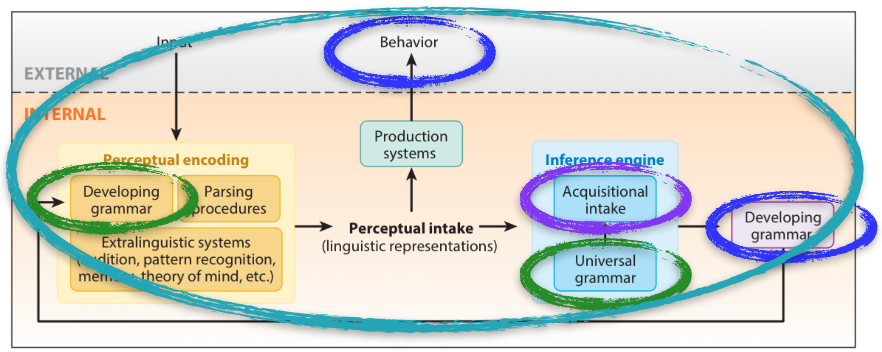
Learning process: Computational-level





Generative model of how the observable data for each verb are created.

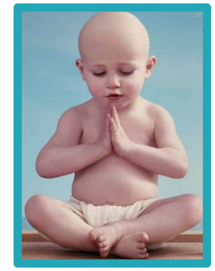
FALL

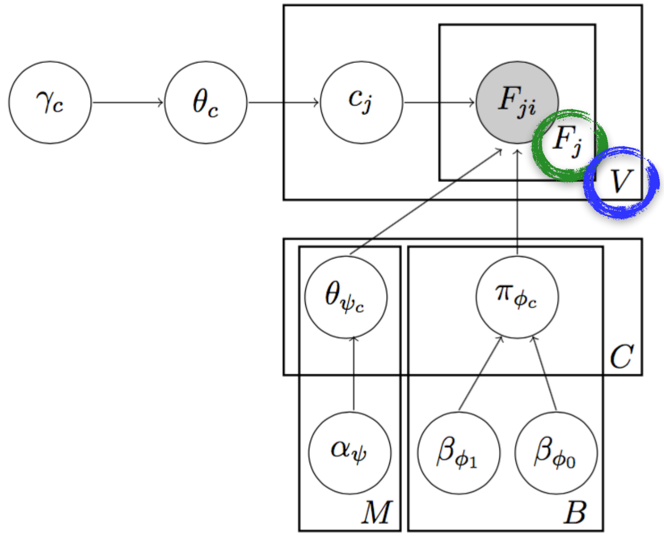


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level





Each verb is observed in a certain number of instances in the input.

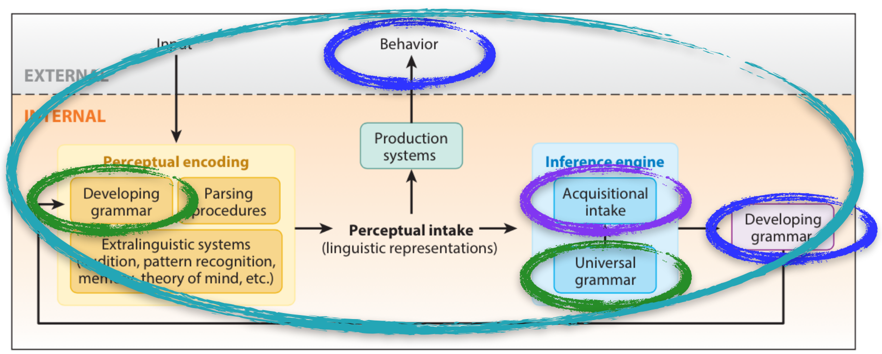
FALL

"it's falling off"

"she fell down"

"don't fall!"

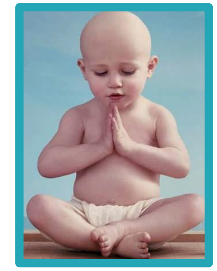
"is London Bridge falling down?"

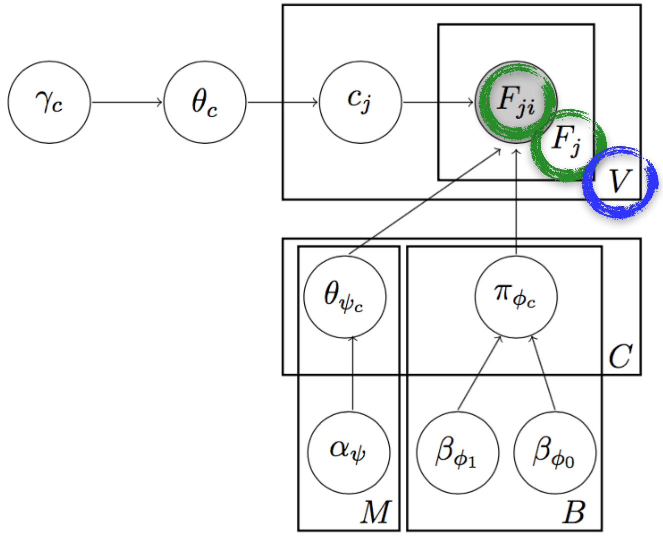


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level





Each instance is observed some number of times.

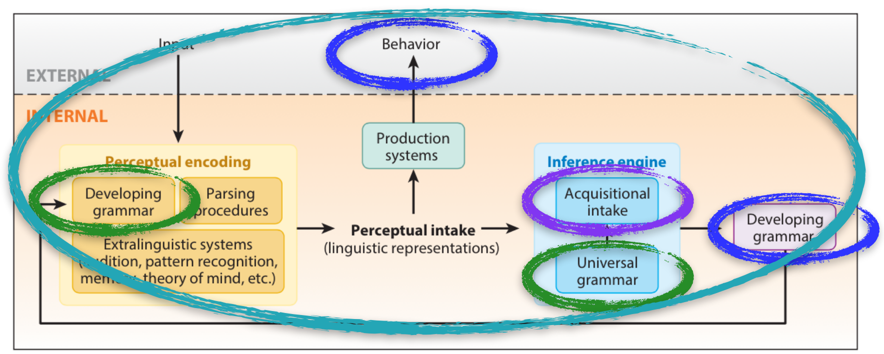
FALL

(3x) "it's falling off"

"she fell down"

"don't fall!"

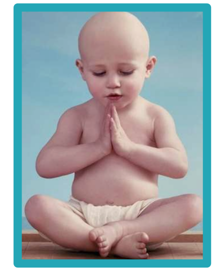
"is London Bridge falling down?"

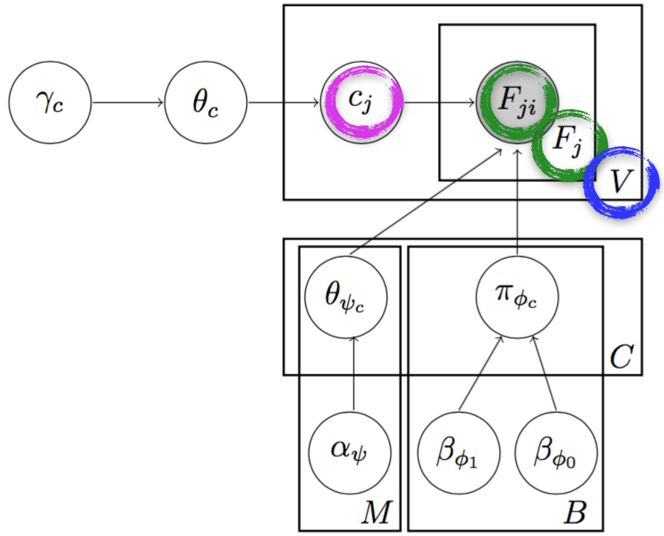


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level





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

FALL

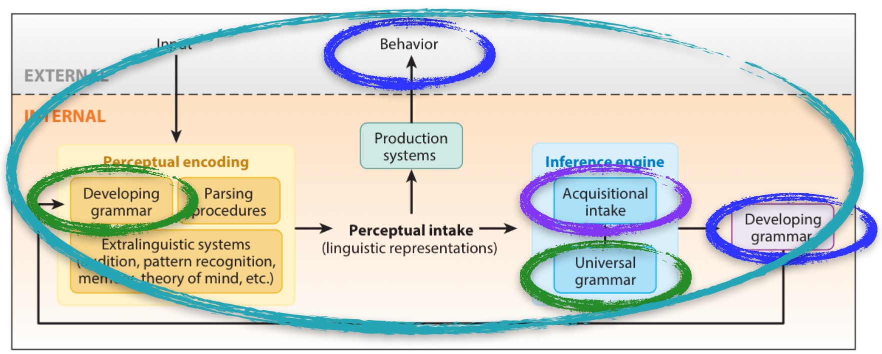
unaccusatives

(3x) "it's falling off"

"she fell down"

"don't fall!"

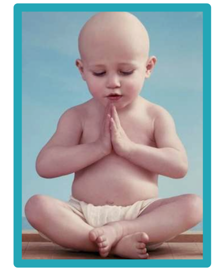
"is London Bridge falling down?"

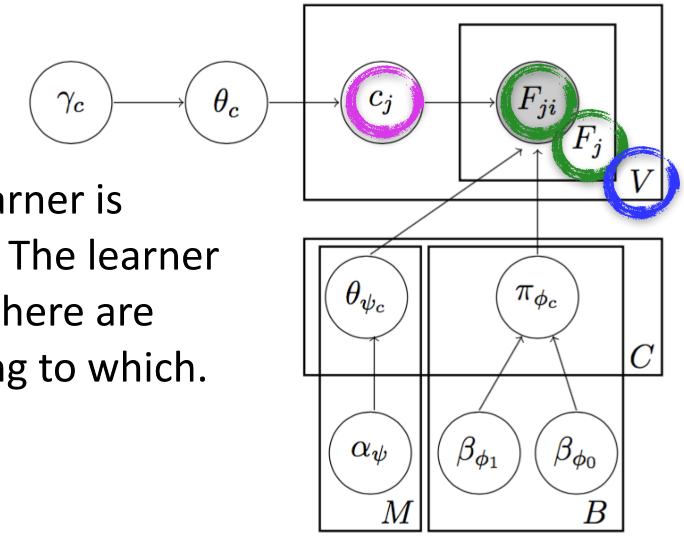


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level

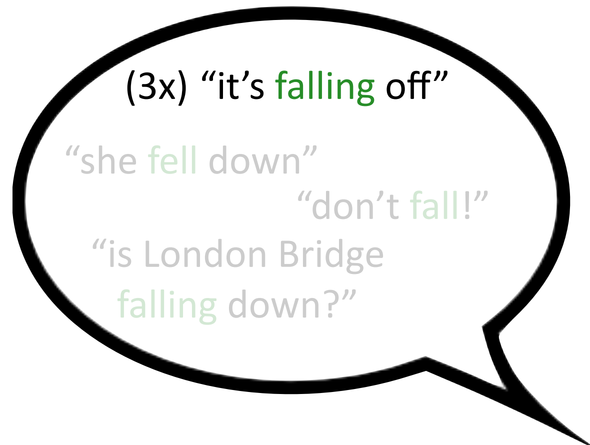


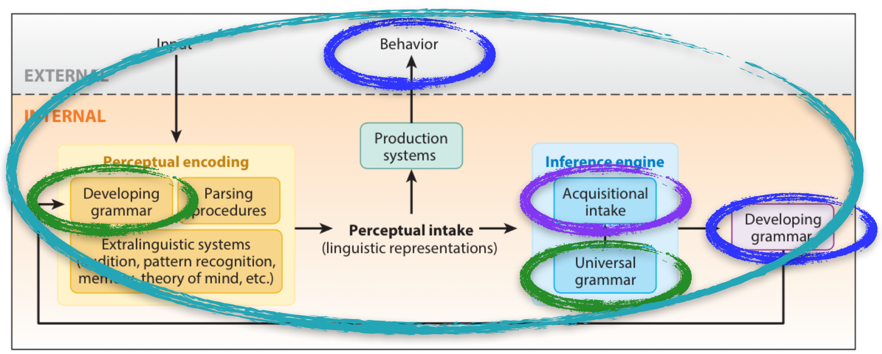


The class is the main thing the learner is trying to figure out for each verb. The learner doesn't know how many classes there are beforehand, or which verbs belong to which.

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

FALL *unaccusatives*

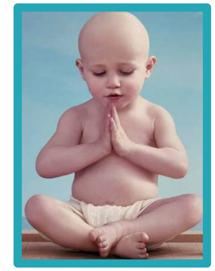


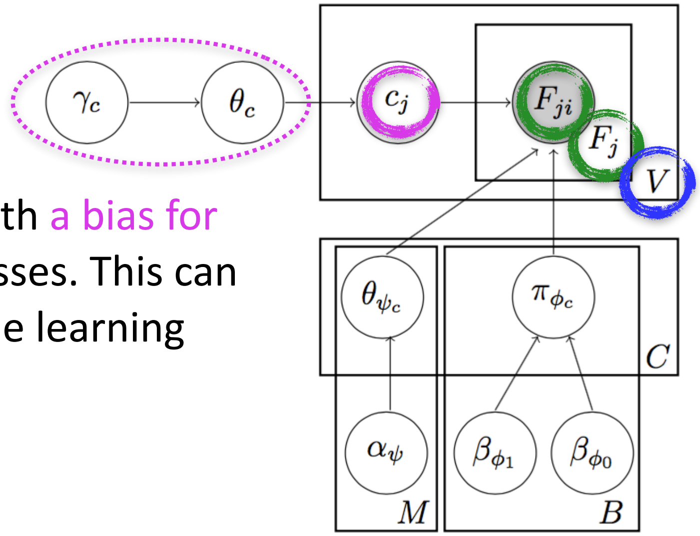


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level





However, the learner does begin with a bias for fewer classes, rather than more classes. This can be adjusted automatically during the learning process.

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

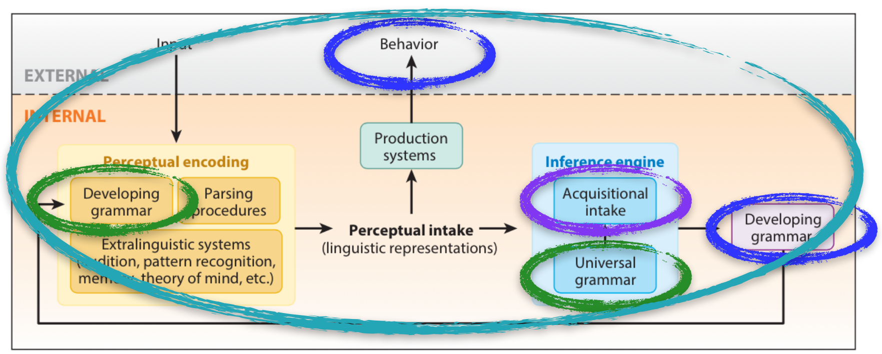
FALL *unaccusatives*

(3x) "it's falling off"

"she fell down"

"don't fall!"

"is London Bridge falling down?"



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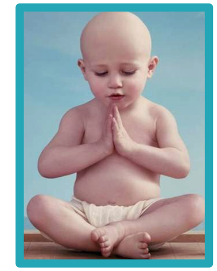
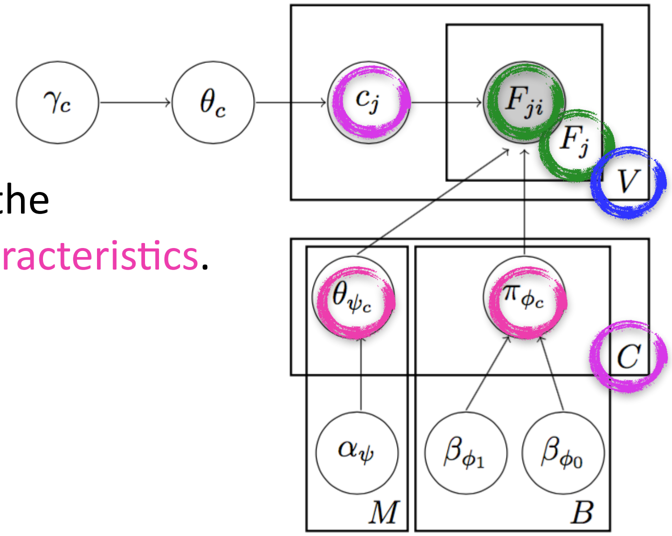
Pearl & Sprouse in progress

Learning process: Computational-level





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

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

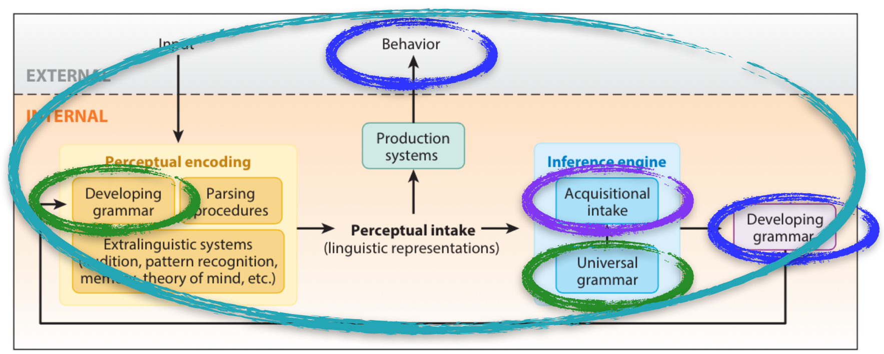
FALL *unaccusatives*

(3x) "it's falling off"

"she fell down"

"don't fall!"

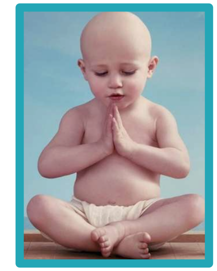
"is London Bridge falling down?"

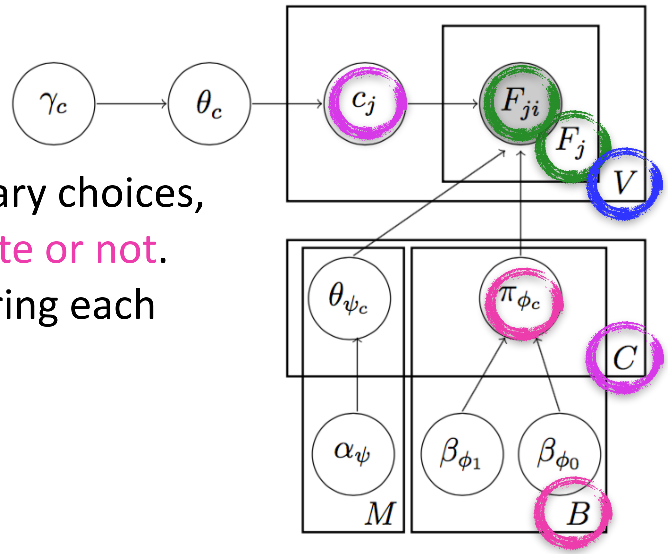


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level





These characteristics can include binary choices, such as whether the subject is animate or not. Each class has a probability of preferring each option.

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

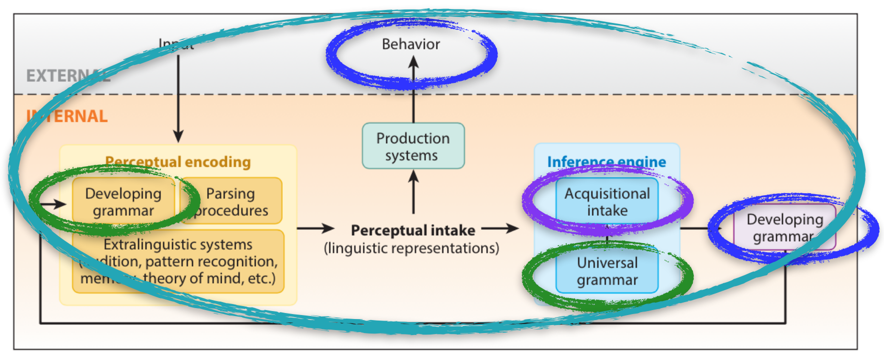
FALL *unaccusatives*

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

"she fell down"

"don't fall!"

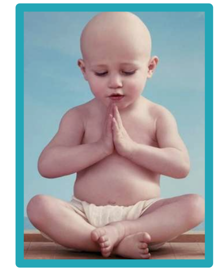
"is London Bridge falling down?"



Lidz & Gagliardi 2015

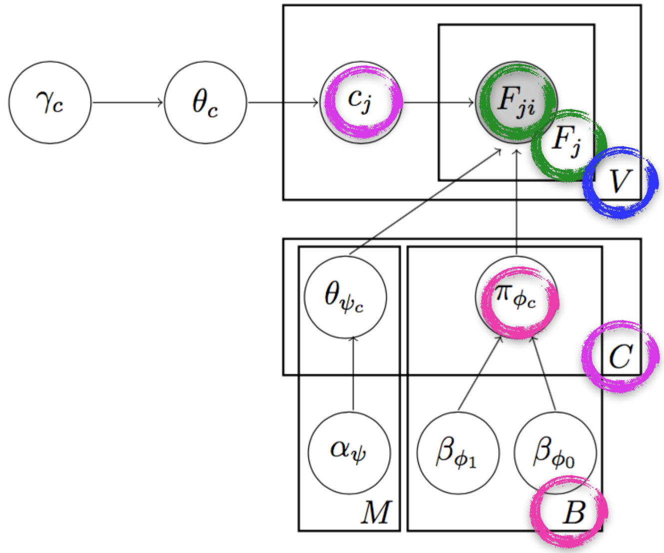
Pearl & Sprouse in progress

Learning process: Computational-level



Binary properties include:

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

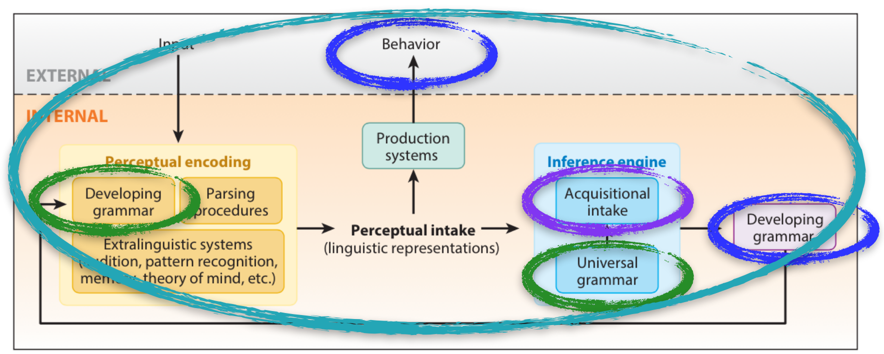


Each verb belongs to some class which determines its linguistic behavior.

FALL *unaccusatives*

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

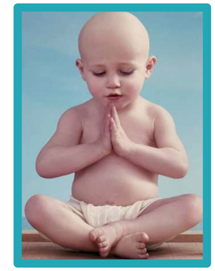
"she fell down"
"don't fall!"
"is London Bridge falling down?"

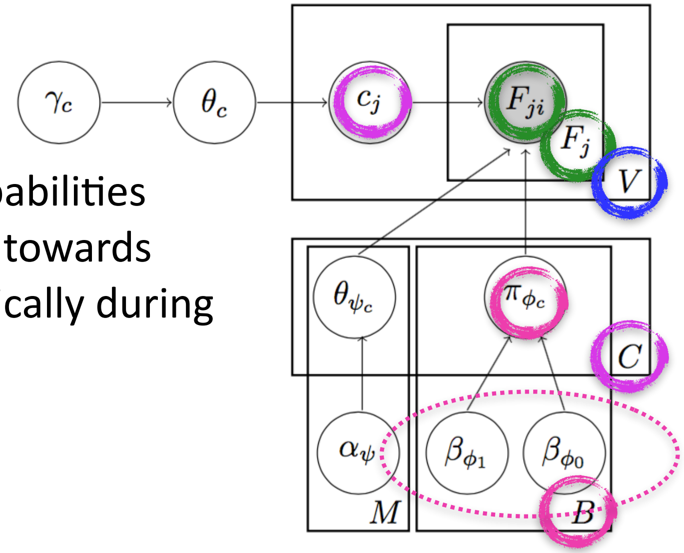


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level

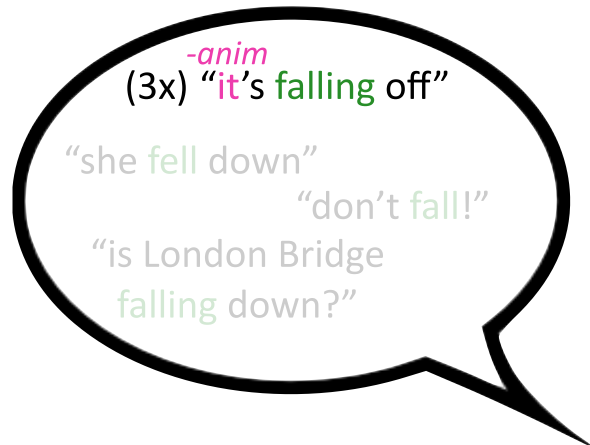


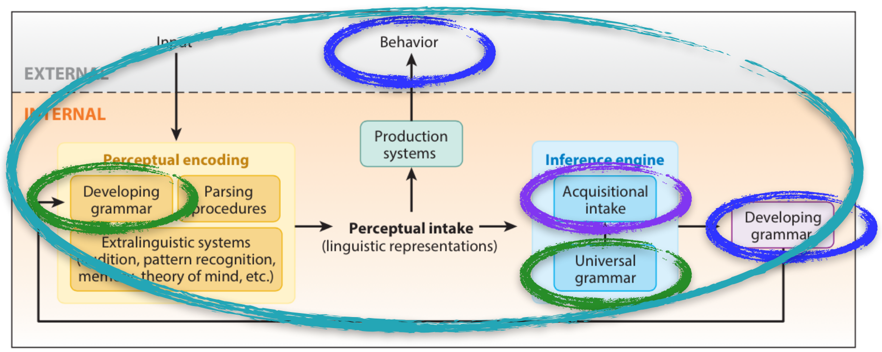


The learner doesn't know these probabilities beforehand, and begins with no bias towards either. This can be adjusted automatically during the learning process.

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

FALL *unaccusatives*

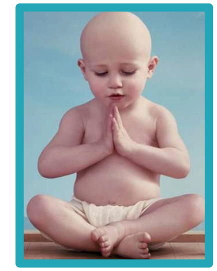


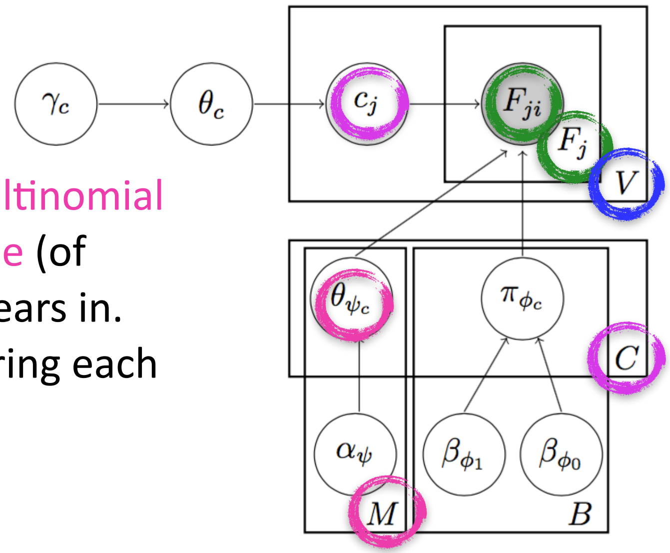


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level



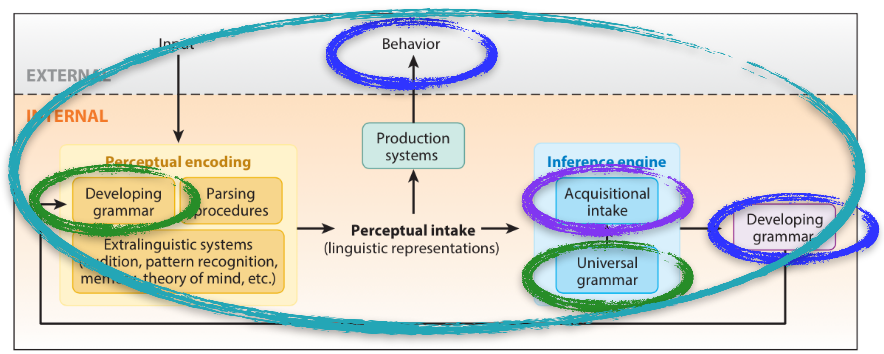


These characteristics also include multinomial choices, such as which syntactic frame (of however many there are) a verb appears in. Each class has a probability of preferring each option.

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

FALL | *unaccusatives*

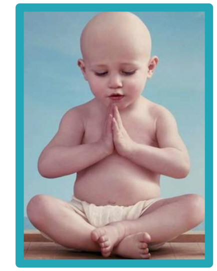
-anim
(3x) "it's falling off"
NP V *PRT*
"she fell down"
"don't fall!"
"is London Bridge falling down?"



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level



Multinomial properties include:

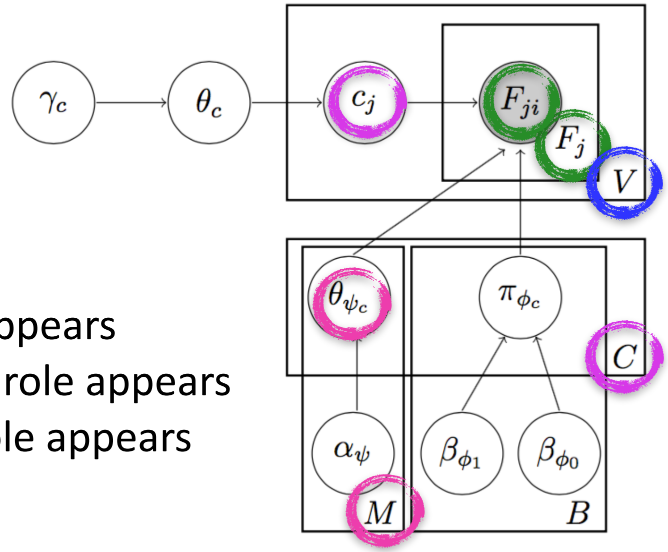
which syntactic frame is used

(if -exp-mapping)

where the Agent-like/Highest role appears

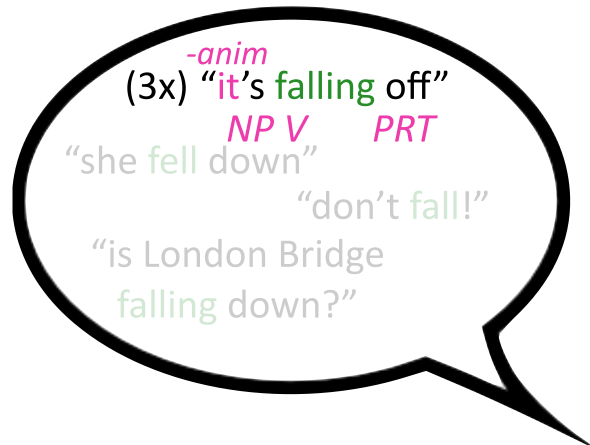
where the Patient-like/next-Highest role appears

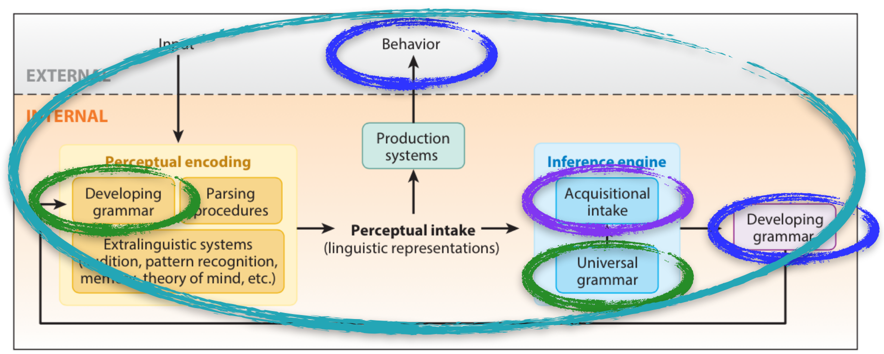
where the Goal-like/third-highest role appears



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

FALL unaccusatives

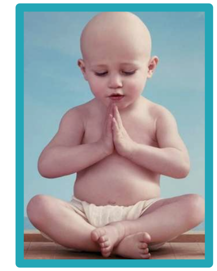


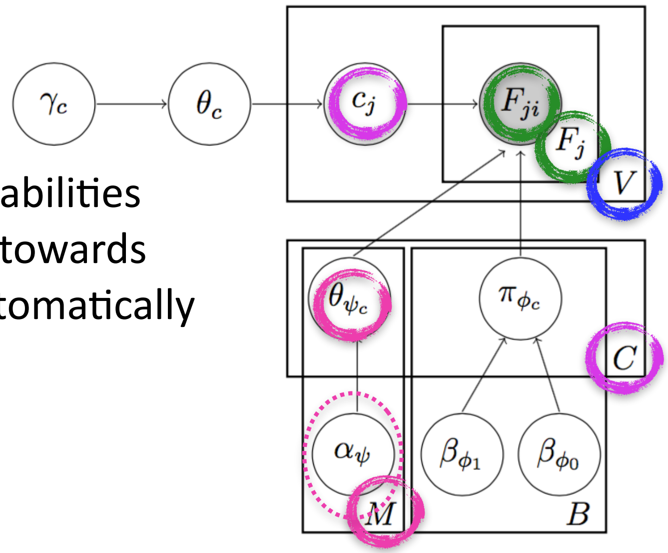


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level

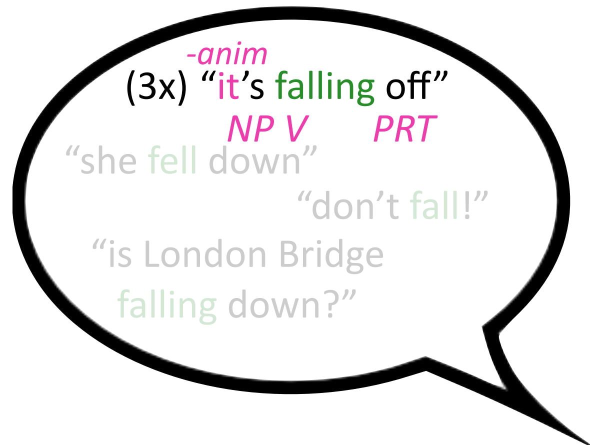


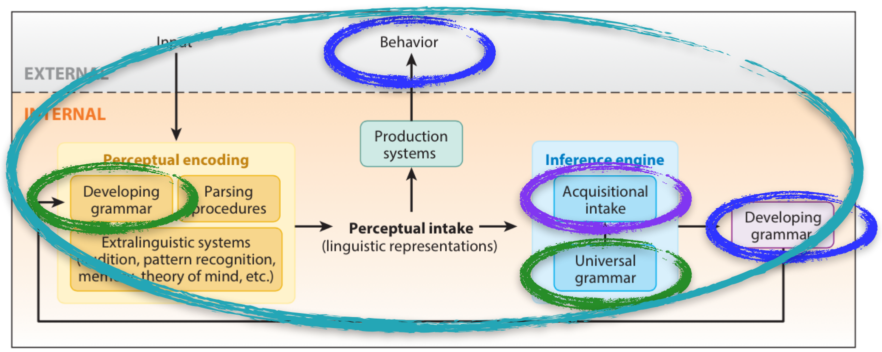


The learner doesn't know these probabilities beforehand, and begins with no bias towards any of them. This can be adjusted automatically during the learning process.

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

FALL *unaccusatives*

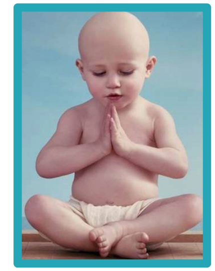


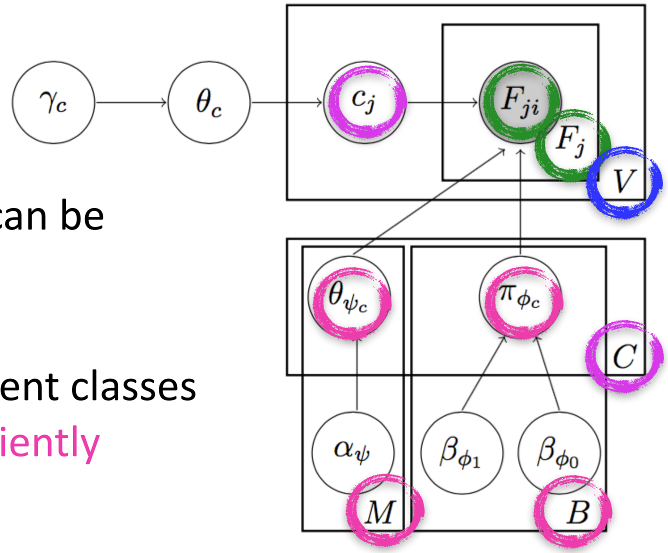


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level





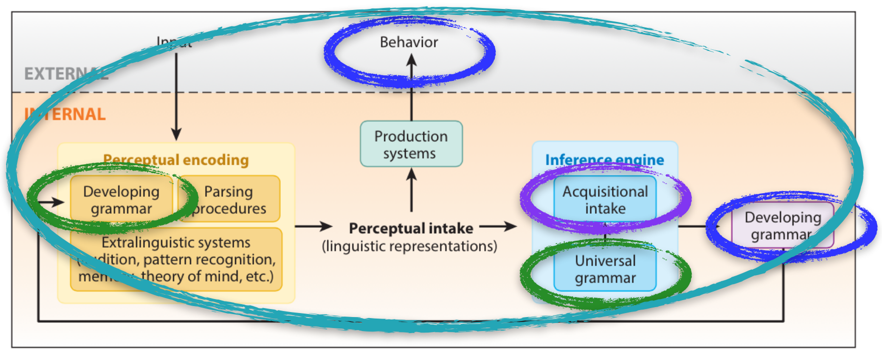
All the characteristics for each class can be inferred during the learning process.

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

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

FALL unaccusatives

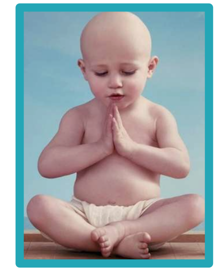
-anim
(3x) "it's falling off"
NP V PRT
"she fell down"
"don't fall!"
"is London Bridge falling down?"

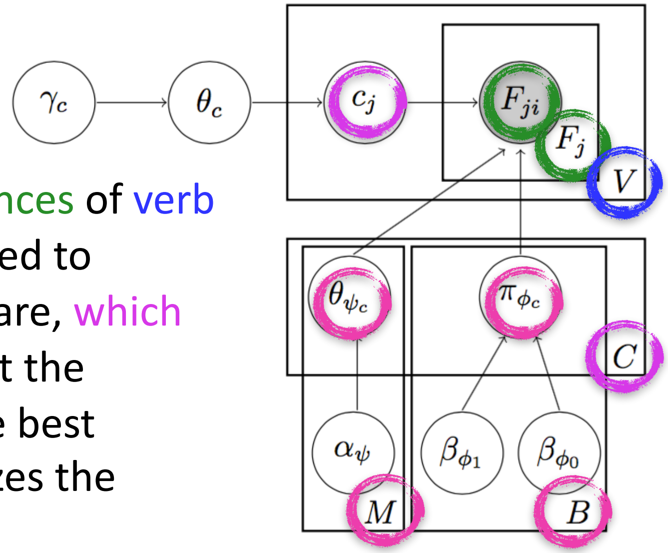


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level





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

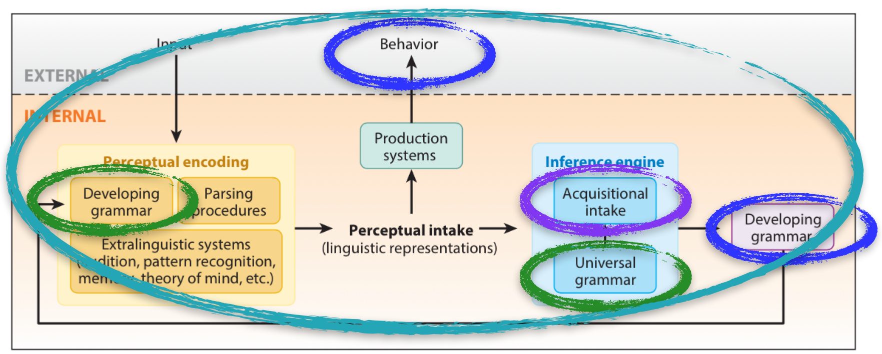
FALL *unaccusatives*

Summary: 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, and what the characteristics are of each class. The best answer will be the one that maximizes the probability of the observed data.

-anim
(3x) "it's falling off"
NP V *PRT*
"she fell down"
"don't fall!"
"is London Bridge falling down?"

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

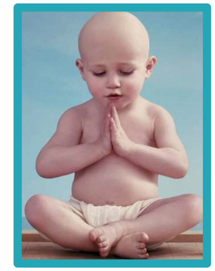
+ Gibbs sampling (method guaranteed to find optimal answer, given sufficient time to search the hypothesis space)

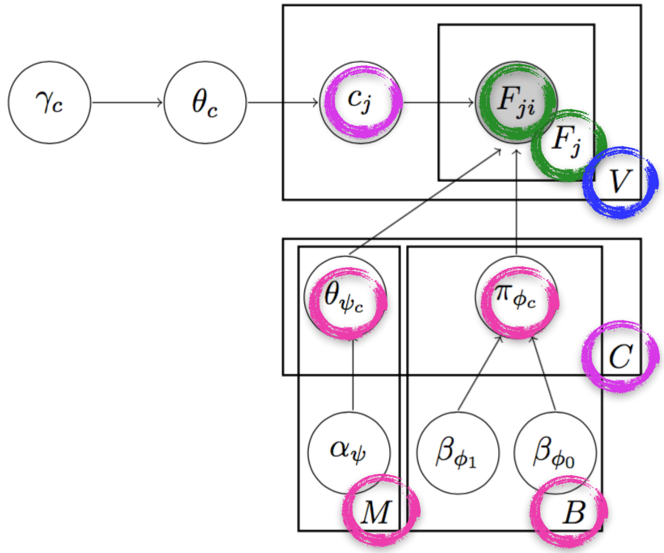


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

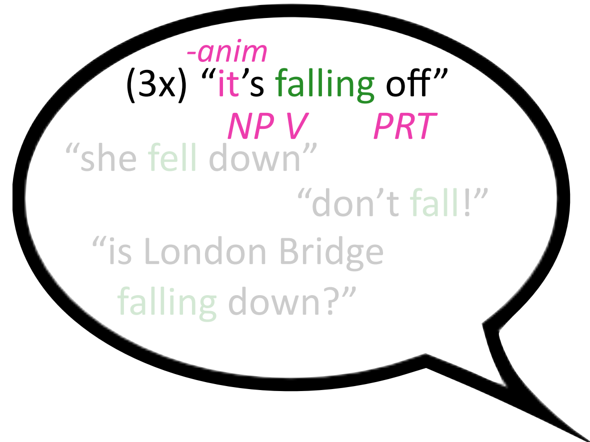
Learning process: Computational-level



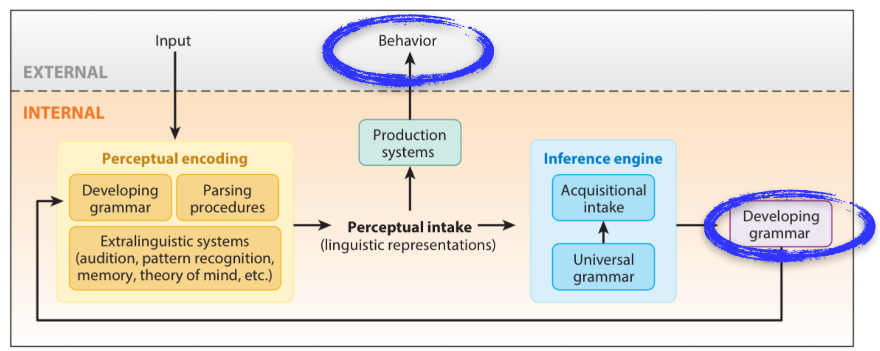


Each verb belongs to some class which determines its linguistic behavior.

FALL unaccusatives



Goal: Determine if the information provided (syntactic, conceptual, and semantic-syntactic cues) is sufficient to identify useful verb classes this way.

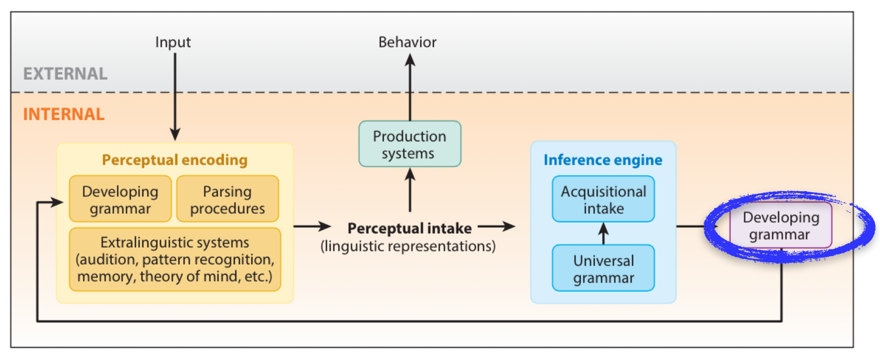


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

Adult knowledge is the eventual target state for acquisition, and there are a variety of verb distinctions that have different syntactic and/or thematic role implications. Do some of these distinctions fall out directly by using the syntactic, conceptual, and semantic-syntactic cues we're using?



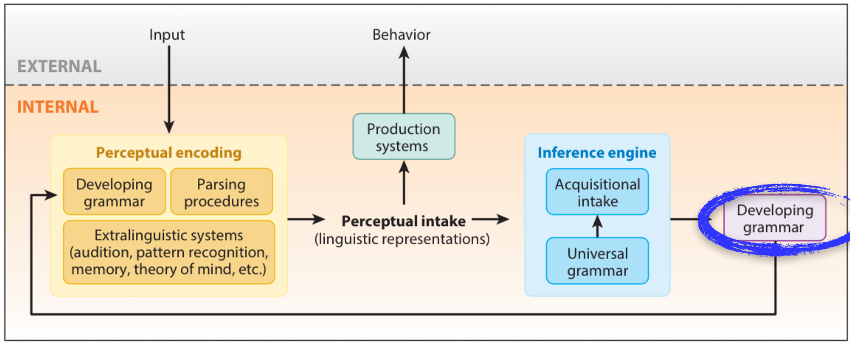
Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

Adult knowledge is the eventual target state for acquisition, and there are a variety of verb distinctions that have different syntactic and/or thematic role implications. Do some of these distinctions fall out directly by using the syntactic, conceptual, and semantic-syntactic cues we're using?

Given the input data we have from the Brown-Eve+Valian corpus (which is directed at children age 2;8 and younger), we should probably focus on distinctions children seem to have made by age three.



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

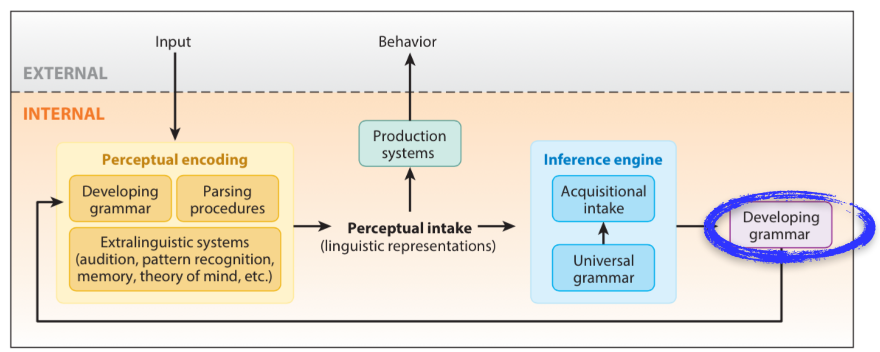
Target state: Useful verb classes

Cues to transitives (allowing a single object) seem to be recognized as early as two years old in English: Naigles 1990, Naigles & Kako 1993, Yuan & Fisher 2009.

Transitive, single object "Jack ___ it."

+= bite, eat, forget, kick, understand, …

-= cough, laugh, sleep, sneeze, …



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

Verbs that can be used transitively (aren't purely intransitive) can be passivized, though children in English seem to only be able to recognize verbs in passives around age three: Gordon & Chafetz 1990, O'Brien et al. 2006, Crain et al., 2009, Nguyen et al. 2016.

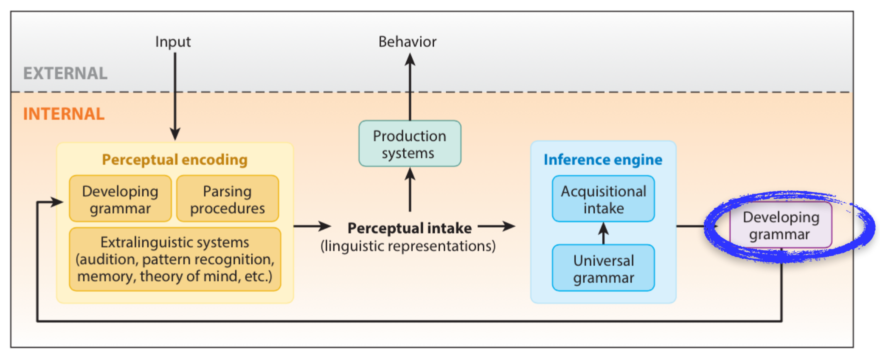
Transitive, single object "Jack ___ it."

Passivizable "It was ___-en."

Patient-like

+= bite, eat, forget, kick, understand, …

-= cough, laugh, sleep, sneeze, …



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

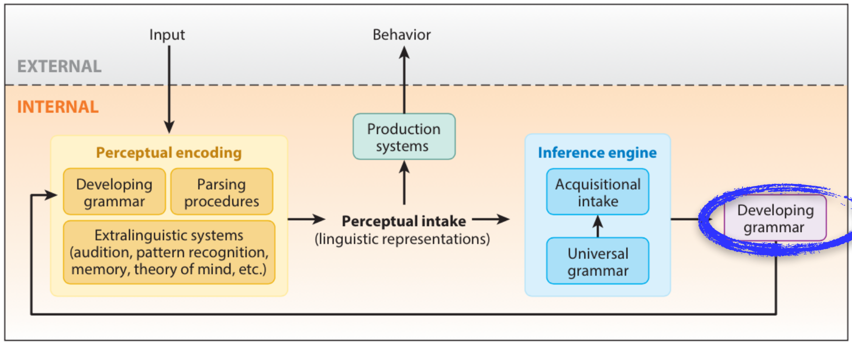
Verbs allowing the intransitive use (no object) are recognized as early as 28 months: Scott & Fisher 2009.

Transitive, single object "Jack ___ it."

Passivizable "It was ___-en." *Patient-like*

Intransitive "Jack ___ ."

+= chirp, eat, jump, understand, …
-= buy, give, thank, want …



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

Verbs allowing the ditransitive use (two objects: indirect and direct) are recognized by age three: Gropen, Pinker, Hollander, Goldberg, & Wilson 1989, Snyder & Stromswold 1997, Campbell & Tomasello 2001, Conwell & Demuth 2007, Thothathiri & Snedeker 2008.

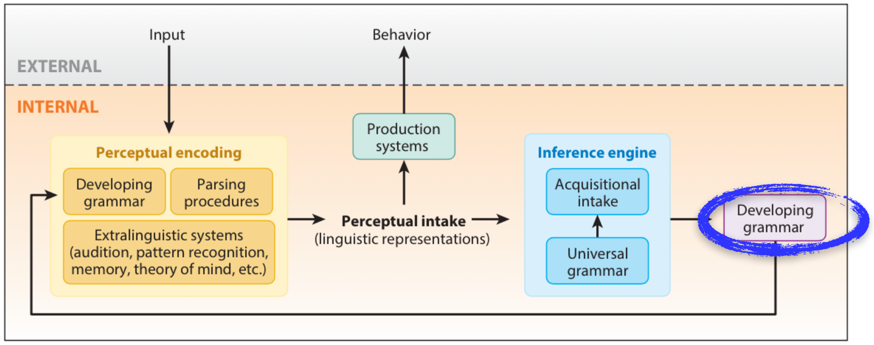
Transitive, single object "Jack ___ it."

Passivizable "It was ___-en."
Patient-like

Intransitive "Jack ___ ."

Transitive, double object "Jack ___ Lily the thing."

+= allow, bring, pour, send, …
-= bite, eat, laugh, sleep, understand…



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

Children seem to begin forming a class of verbs used as unaccusatives by age two: Déprez & Pierce 1993, Snyder & Stromswold 1997, Bunger & Lidz 2004.

Transitive, single object “Jack ___ it.”

Unaccusative “Jack ___.” *Patient-like*

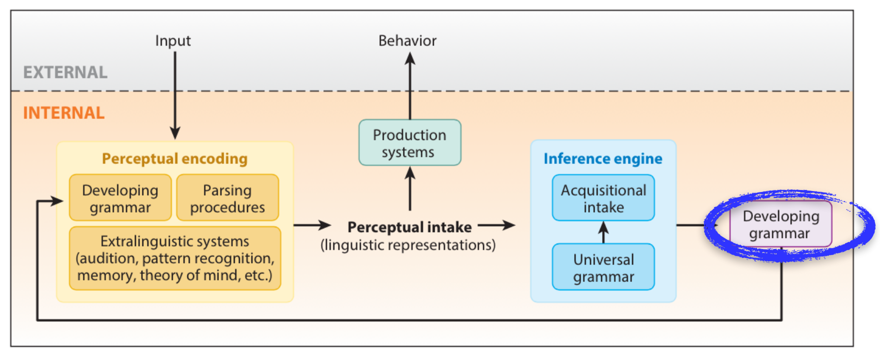
Passivizable “It was ___-en.” *Patient-like*

Intransitive “Jack ___ .”

Transitive, double object “Jack ___ Lily the thing.”

+= bounce, break, freeze, melt,…

-= call, find, help, see,…



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

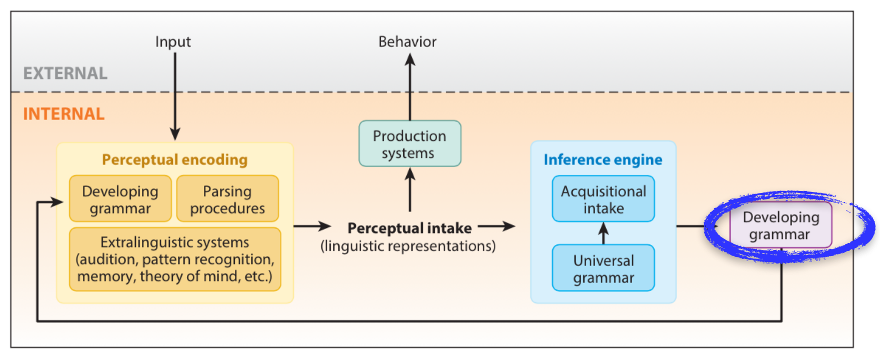
Target state: Useful verb classes

Children seem to begin forming a class of verbs used as unergatives by age two: Bunger & Lidz 2008.

Transitive, single object	"Jack ___ it."	Unaccusative	"Jack ___." *Patient-like*
Passivizable	"It was ___-en." *Patient-like*	Unergative	"Jack ___." *Agent-like*
Intransitive	"Jack ___ ."		
Transitive, double object	"Jack ___ Lily the thing."		

+= cry, dance, listen, play,…

-= bounce, follow, push, shake,…



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

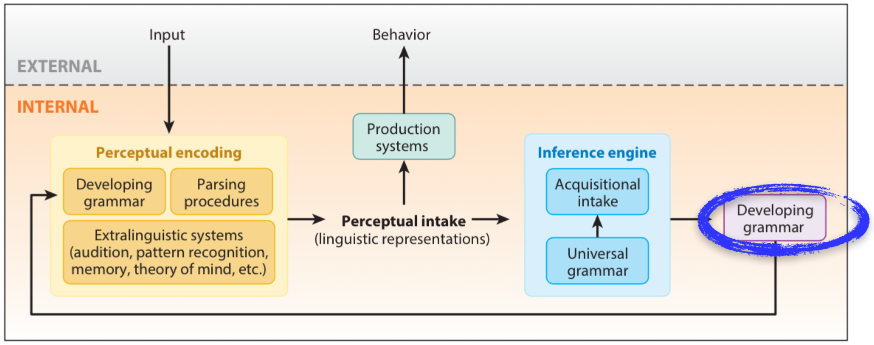
Target state: Useful verb classes

Children seem to begin forming a class of verbs that take *that*-complements by age three: Kidd, Lieven, & Tomasello 2006.

Transitive, single object	"Jack ___ it."	Unaccusative	"Jack ___." *Patient-like*
Passivizable	"It was ___-en." *Patient-like*	Unergative	"Jack ___." *Agent-like*
Intransitive	"Jack ___ ."	*that*-complement	"Jack ___that Lily's nice."
Transitive, double object	"Jack ___ Lily the thing."		

+= care, decide, know, learn…

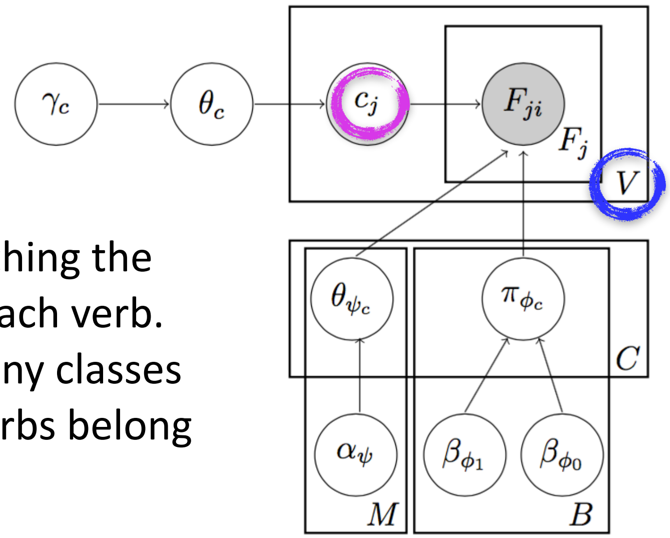
-= bounce, follow, push, shake,…



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Evaluating the results



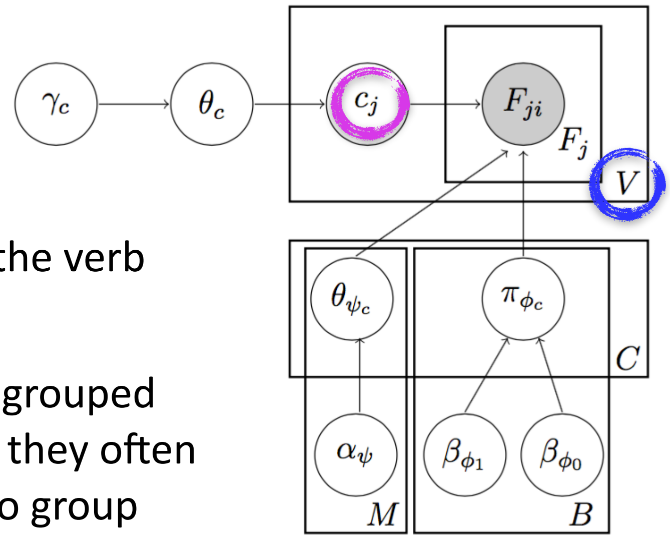
Each verb belongs to some class which determines its linguistic behavior.

FALL *unaccusatives*

Remember: The class is the main thing the learner is trying to figure out for each verb. The learner doesn't know how many classes there are beforehand, or which verbs belong to which.

Pearl & Sprouse in progress

Target state: Evaluating the results



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

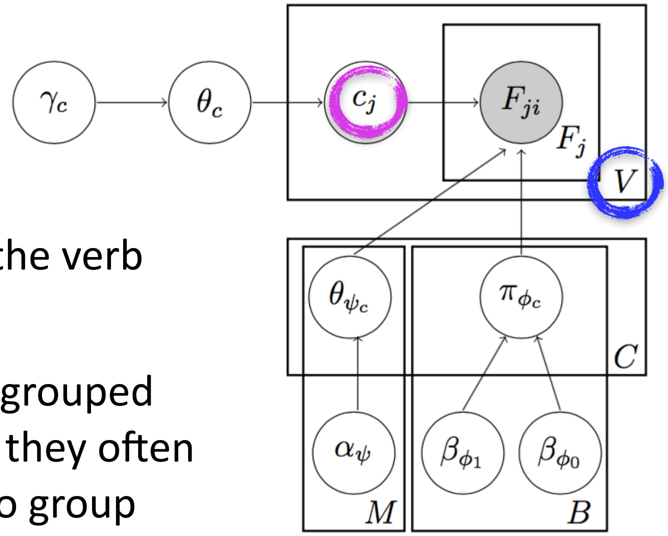
FALL *unaccusatives*

Question: How homogeneous are the verb classes each learner infers?

That is, when we look at the verbs grouped together into an inferred class, are they often the same kind of verb? It's useful to group together verbs of the same kind.

Pearl & Sprouse in progress

Target state: Evaluating the results



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Implementation:
Random Index

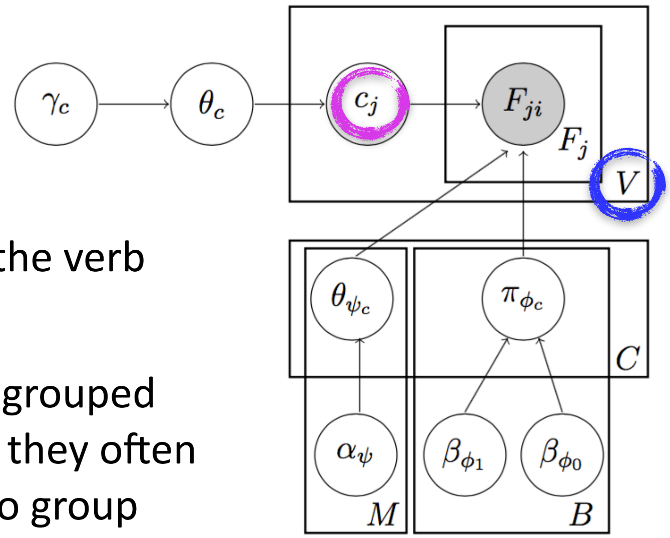
 

0.0 <= RI <= 1.0

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

Pearl & Sprouse in progress

Target state: Evaluating the results



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Implementation:
Random Index

0.0 <= RI <= 1.0

For each pair of verbs in the inferred classes:

verb_i verb_j

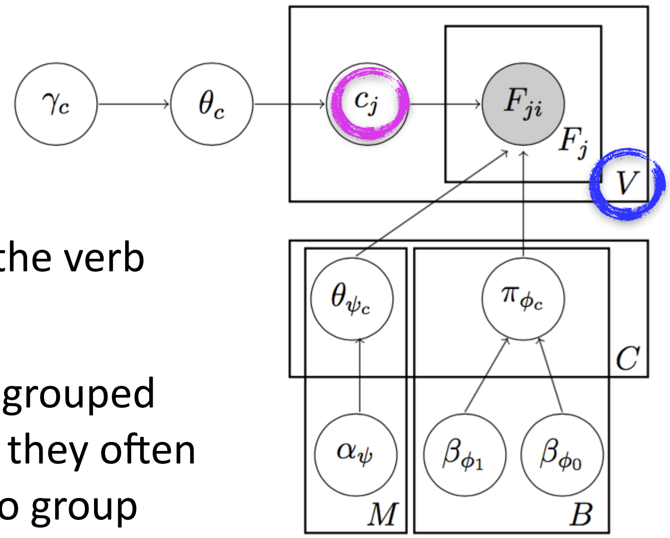
Intuition: Get credit for putting things together that belong together and keeping things apart that don't belong together.

Inferred Class

		Same class	Different class
True	Same class	True Positive	False Negative
	Different class	False Positive	True Negative

Pearl & Sprouse in progress

Target state: Evaluating the results



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FALL   *unaccusatives*

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For each pair of verbs in the inferred classes:

$verb_i$ $verb_j$

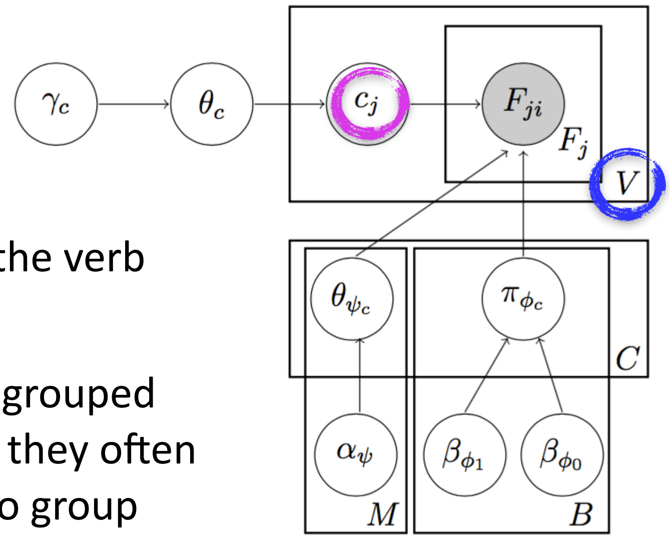
Intuition: Get credit for putting things together that belong together and keeping things apart that don't belong together.

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

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

Pearl & Sprouse in progress

Target state: Evaluating the results



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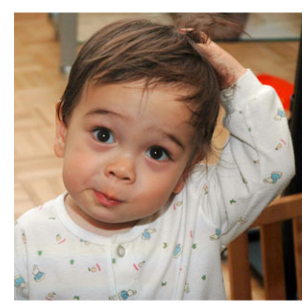
Implementation:
Random Index

0.0 <= RI <= 1.0

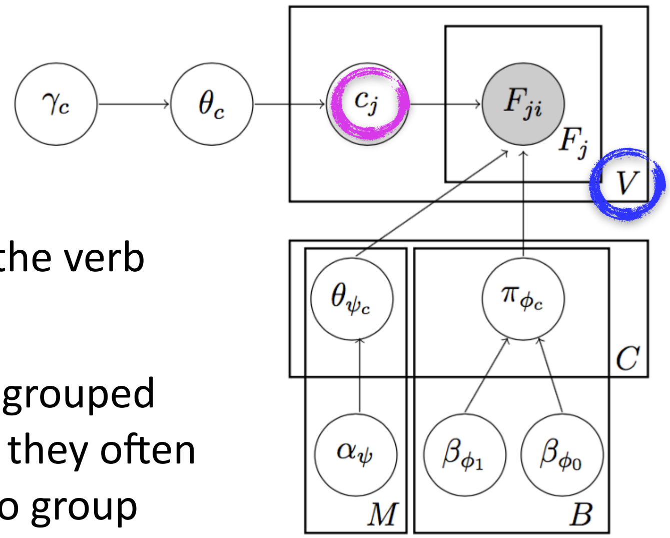
Intuition: Get credit for putting things together that belong together and keeping things apart that don't belong together.

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



Pearl & Sprouse in progress

Target state: Evaluating the results



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

FALL *unaccusatives*

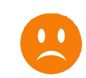
Question: How homogeneous are the verb classes each learner infers?

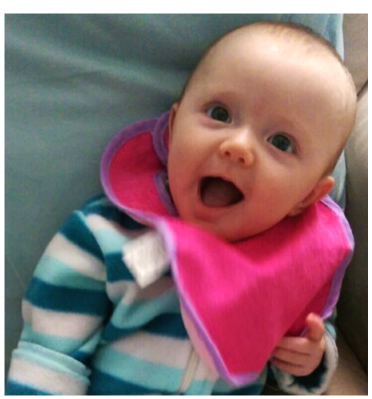
That is, when we look at the verbs grouped together into an inferred class, are they often the same kind of verb? It's useful to group together verbs of the same kind.

Implementation: Adjusted Random Index

-1.0 <= ARI <= 1.0

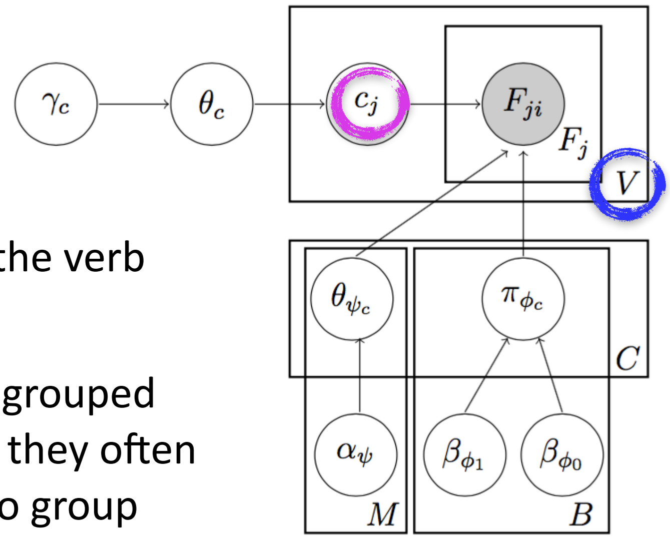
Compared against the expected value of the Random Index:

1.0 = perfect classification 
>0 = better than chance
0 = chance performance 
<0 = worse than chance
-1.0 = perfectly awful performance 



Pearl & Sprouse in progress

Target state: Evaluating the results



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

FALL *unaccusatives*

Question: How homogeneous are the verb classes each learner infers?

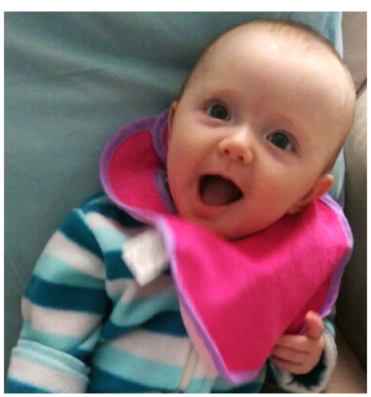
That is, when we look at the verbs grouped together into an inferred class, are they often the same kind of verb? It's useful to group together verbs of the same kind.

Implementation:
Adjusted Random Index

-1.0 <= ARI <= 1.0

Compared against the expected value of the Random Index:

Useful	1.0 = perfect classification >0 = better than chance
Not useful	0 = chance performance <0 = worse than chance -1.0 = perfectly awful performance



Pearl & Sprouse in progress

Target state: Evaluating the results

Distinctions made by two to three years of age, based on behavioral data.

+tense/aspect | *-tense/aspect*

ARI

UTAH | *rUTAH* | *UTAH* | *rUTAH*

+exp-mapping | *-exp-mapping* | *+exp-mapping* | *-exp-mapping* | *+exp-mapping* | *-exp-mapping* | *+exp-mapping* | *-exp-mapping*

Pearl & Sprouse in progress

Target state: Evaluating the results

Distinctions made by two to three years of age, based on behavioral data.

	+tense/aspect				*-tense/aspect*			
	UTAH		*rUTAH*		*UTAH*		*rUTAH*	
ARI	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*

Transitive-double obj
93 verbs
AoA = 3

Intransitives
183 verbs
AoA = 2

Transitive-single obj/ Passivizable
204 verbs
AoA = 2-3

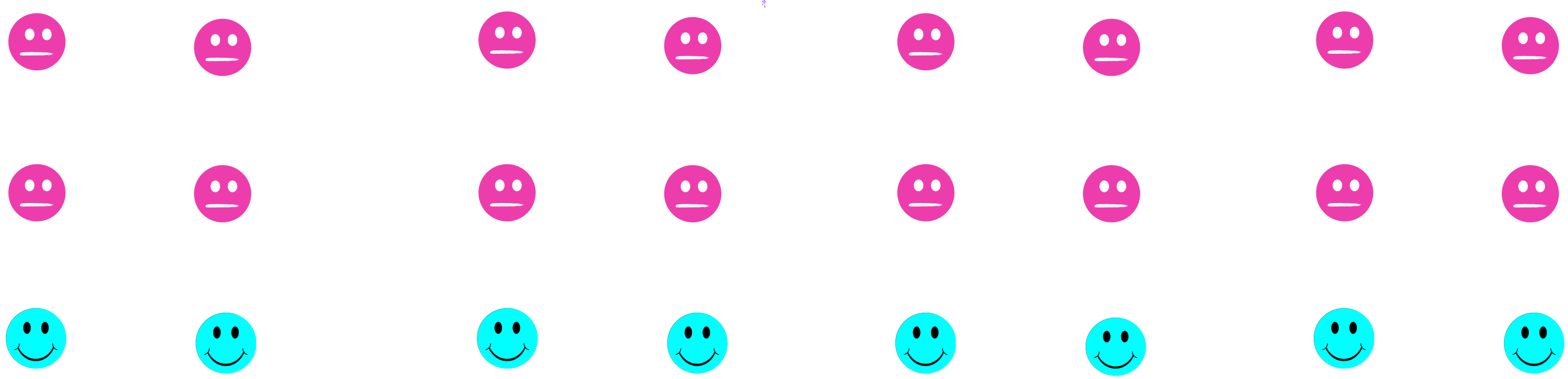
Pearl & Sprouse in progress

Target state: Evaluating the results

Distinctions made by two to three years of age, based on behavioral data.

ARI

	+tense/aspect				*-tense/aspect*			
	UTAH		*rUTAH*		*UTAH*		*rUTAH*	
	+exp-mapping	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*



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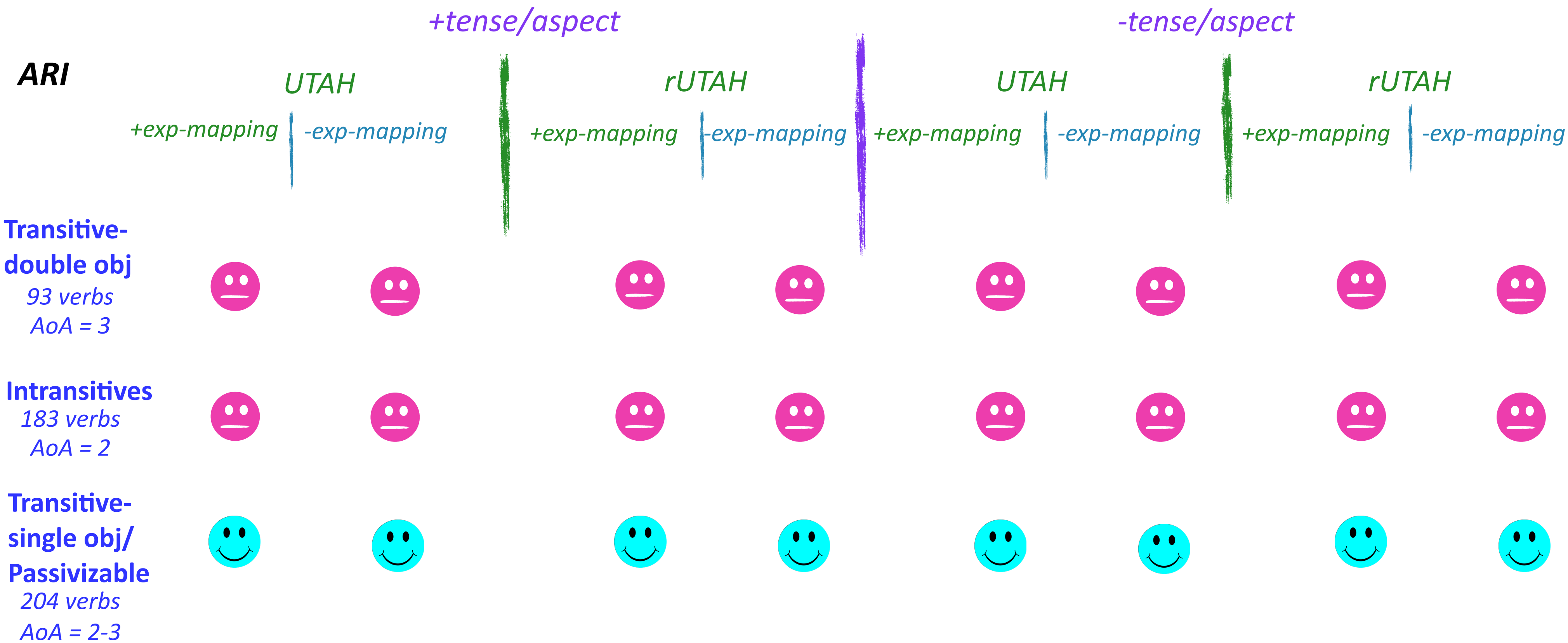
Pearl & Sprouse in progress

Target state: Evaluating the results

Distinctions made by two to three years of age, based on behavioral data.



Learning which verbs allow a single object (and so are passivizable) is easy no matter which assumptions you use.

But learning which verbs allow no objects or two objects is hard, no matter which assumptions you use.

Pearl & Sprouse in progress

Target state: Evaluating the results

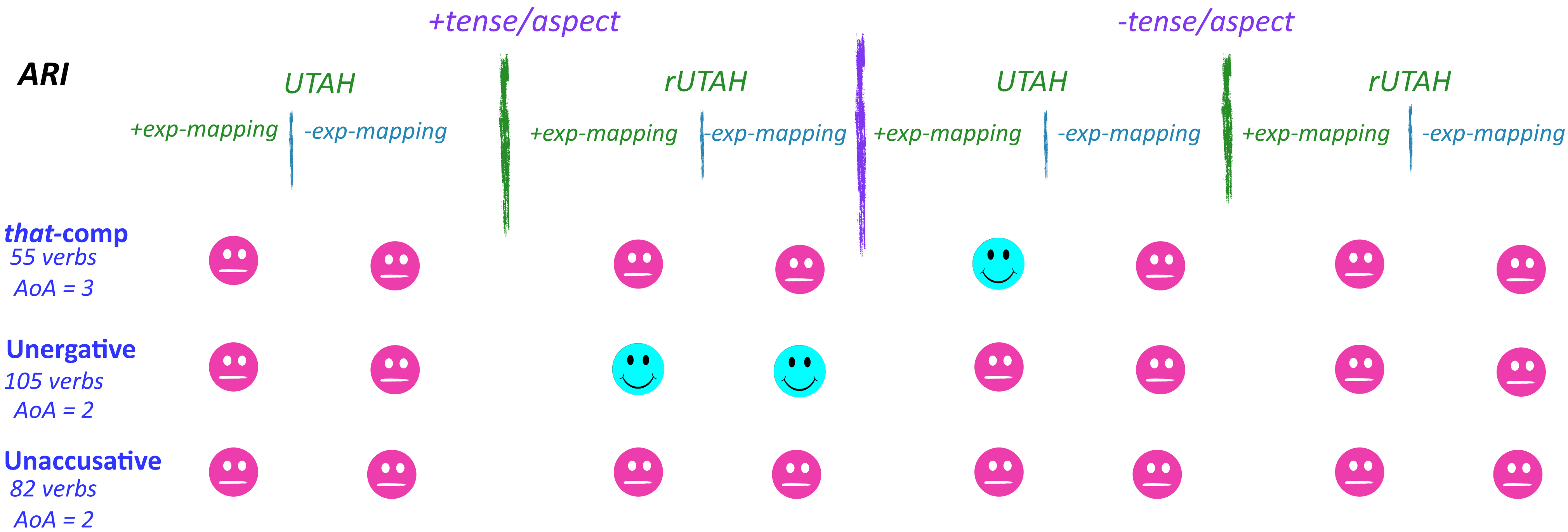
Distinctions made by two to three years of age, based on behavioral data.

ARI	+tense/aspect				-tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping
***that*-comp** *55 verbs* *AoA = 3*								
Unergative *105 verbs* *AoA = 2*								
Unaccusative *82 verbs* *AoA = 2*								

Pearl & Sprouse in progress

Target state: Evaluating the results

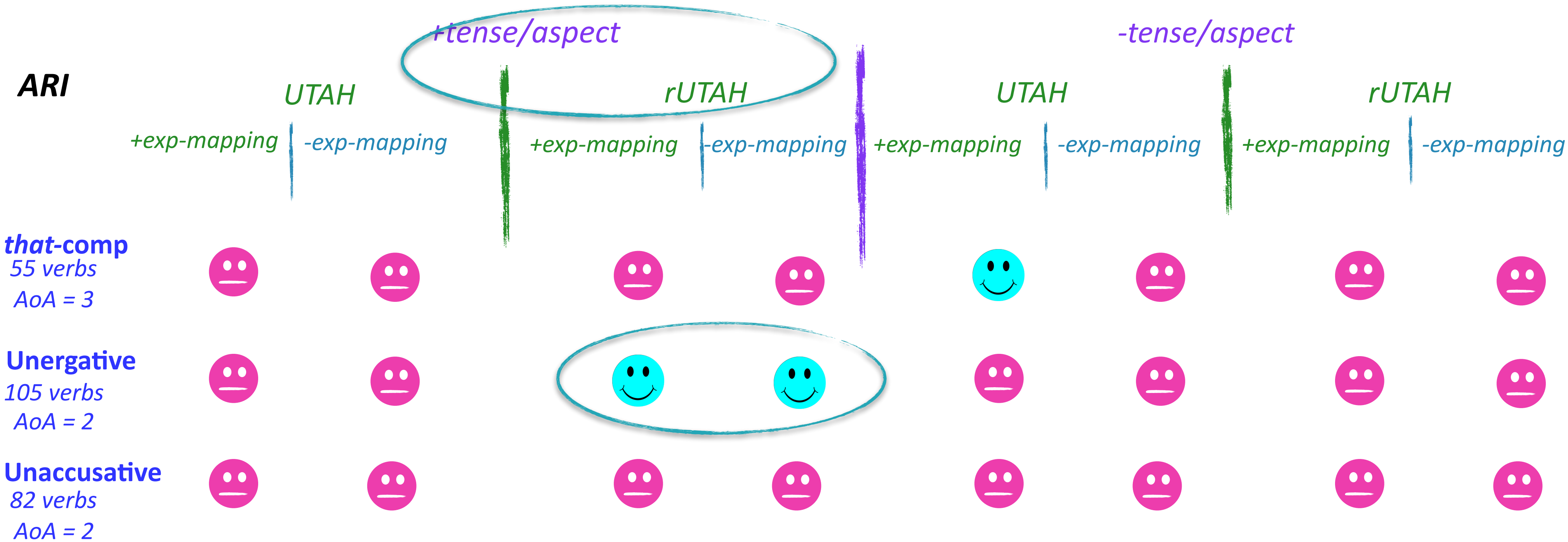
Distinctions made by two to three years of age, based on behavioral data.



Pearl & Sprouse in progress

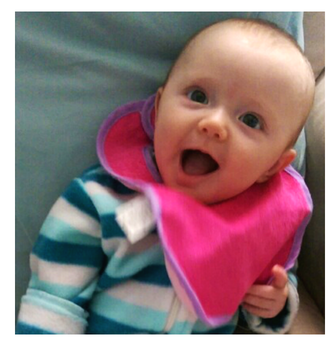
Target state: Evaluating the results

Distinctions made by two to three years of age, based on behavioral data.



Now we see some differences:

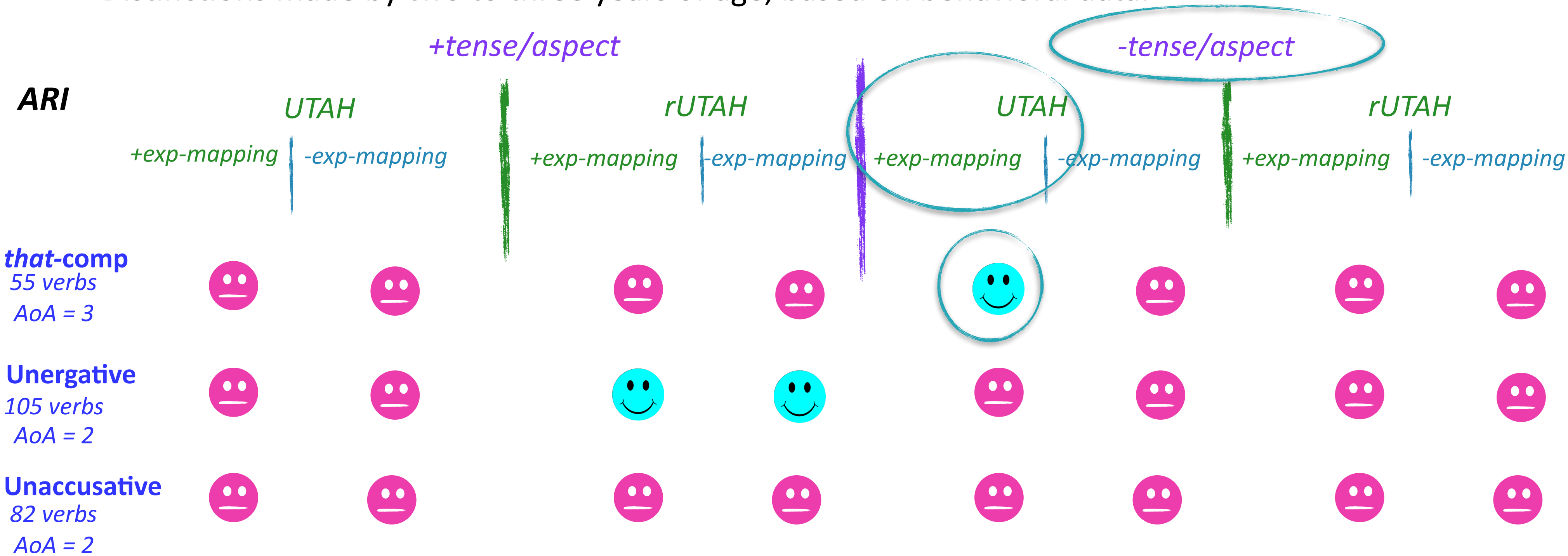
While distinguishing unaccusatives is hard no matter what, distinguishing unergatives is fine if the rUTAH intermediate representation is used with surface tense/aspect morphology in the syntactic frames.



Pearl & Sprouse in progress

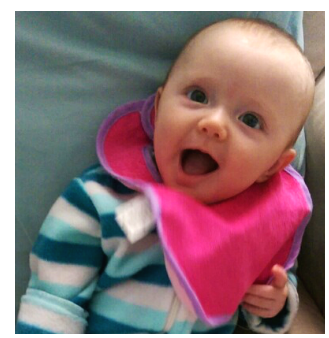
Target state: Evaluating the results

Distinctions made by two to three years of age, based on behavioral data.



Now we see some differences:

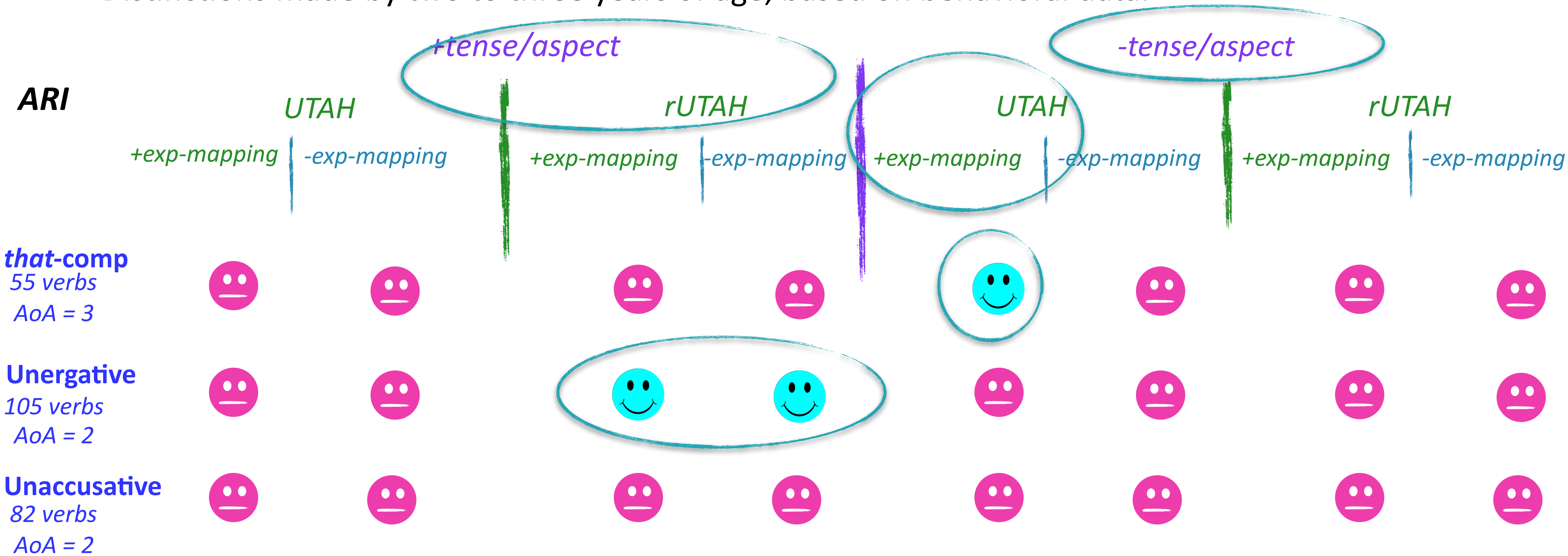
However, only using the UTAH intermediate representation with an expectation of mapping between that representation and syntactic positions as well as ignoring surface tense/aspect morphology will allow a learner to distinguish *that*-complement verbs from these data.



Pearl & Sprouse in progress

Target state: Evaluating the results

Distinctions made by two to three years of age, based on behavioral data.

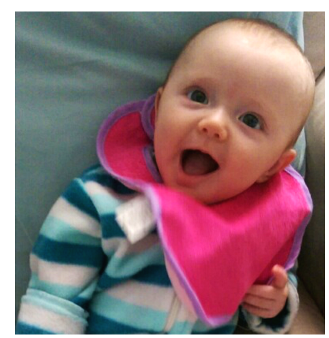


Big picture:

Three of these eight strategies seem to have a leg up on the rest when it comes to making the distinctions children should from these data.

Implication: These combinations of learning assumptions may be more on the right track than the others.

rUTAH, +exp-mapping, +tense/aspect
rUTAH, -exp-mapping, +tense/aspect
UTAH, +exp-mapping, -tense/aspect



Pearl & Sprouse in progress

Learning strategy options

Syntax

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

Subject *Object* *Indirect Object*

-tense/aspect info ← **Choice 3** → **+tense/aspect info**

+exp-mapping: movement is salient because mapping to syntax is fixed ← **Choice 2**

-exp-mapping: syntax mapping distributions are tracked

Mapping to Syntax

UG knowledge

Two good variants

UTAH ← **Choice 1** → **rUTAH**

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

Intermediate representations

Thematic roles map to one of three categories.

Thematic roles are ordered with respect to each other.

thematic-roles

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

Pearl & Sprouse in progress

Learning strategy options

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

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Mapping to Syntax

UG knowledge

Another good variant

UTAH ← **Choice 1** → **rUTAH**

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Pearl & Sprouse in progress

Target state: Evaluating the results

***that*-comp**
55 verbs
AoA = 3

Unergative
105 verbs
AoA = 2

Unaccusative
82 verbs
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93 verbs
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Intransitives
183 verbs
AoA = 2

Transitive-single obj/Passivizable
204 verbs
AoA = 2-3

But wait! Maybe children haven't figured out *every* verb in these classes by age three…

Pearl & Sprouse in progress

Target state: Evaluating the results

***that*-comp**
7 verbs
AoA = 3

Unergative
105 verbs
AoA = 2

Unaccusative
5 verbs
AoA = 2

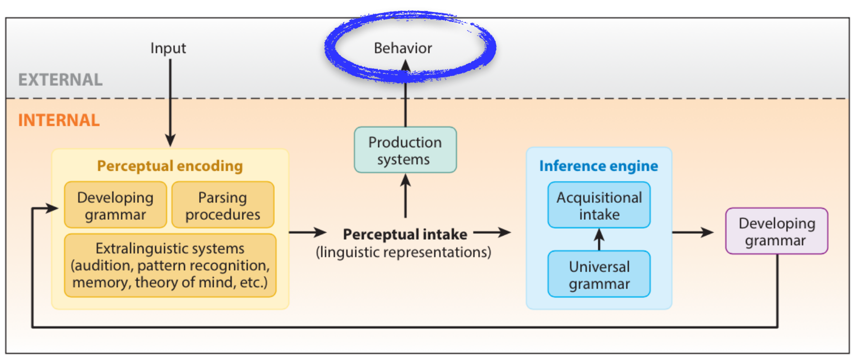
Transitive-double obj
13 verbs
AoA = 3

Intransitives
183 verbs
AoA = 2

Transitive-single obj/ Passivizable
24 verbs
AoA = 2-3

But wait! Maybe children haven't figured out *every* verb in these classes by age three…

Perhaps we should focus on the specific ones that have been behaviorally attested in children by age three.



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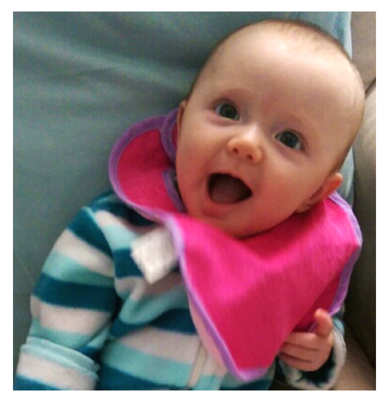

Pearl & Sprouse in progress

Target state: Evaluating the results

Matching the specific distinctions attested in behavioral studies (experimental & spontaneous speech).

	+tense/aspect				*-tense/aspect*			
ARI	*UTAH*		*rUTAH*		*UTAH*		*rUTAH*	
	+exp-mapping	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
***that*-comp** *7 verbs*								
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Pearl & Sprouse in progress

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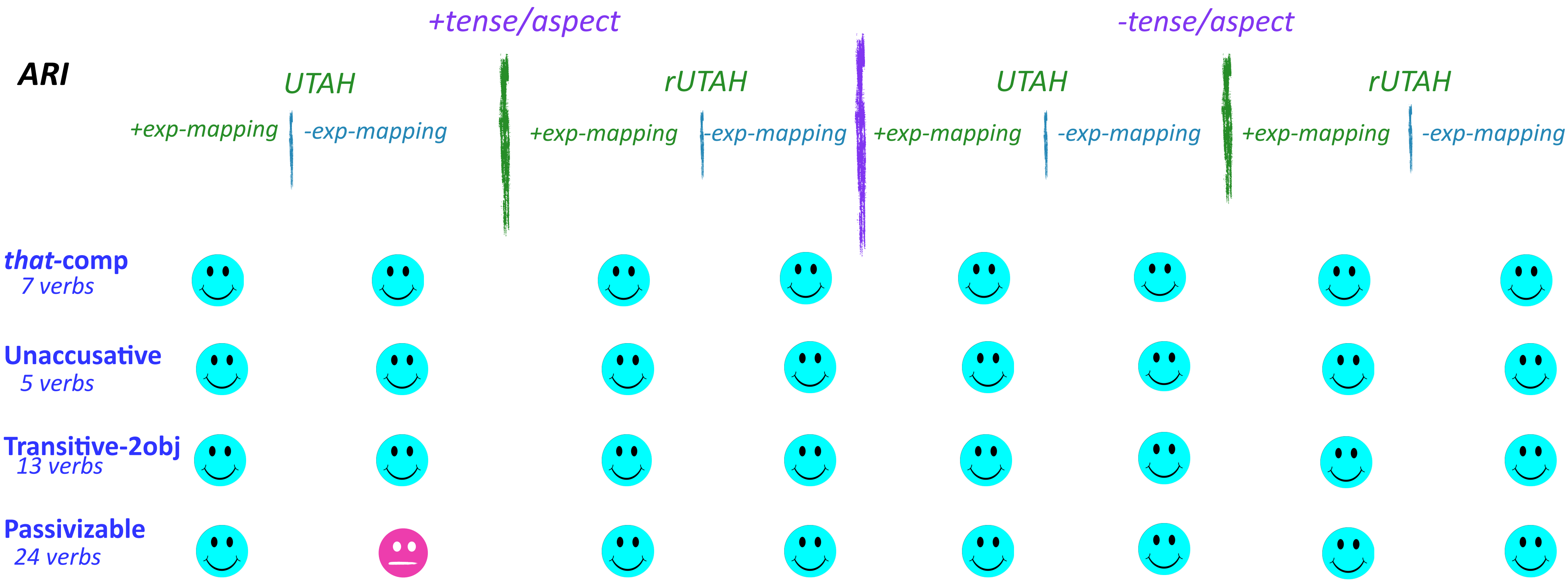

Pearl & Sprouse in progress

Target state: Evaluating the results

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ARI	*+tense/aspect*				*-tense/aspect*			
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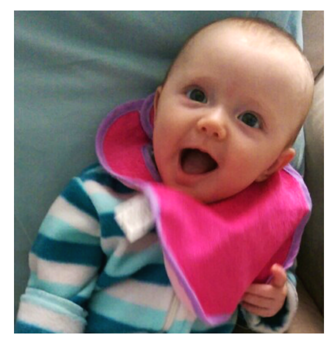
	+exp-mapping	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
***that*-comp** *7 verbs*	☺	☺	☺	☺	☺	☺	☺	☺
Unaccusative *5 verbs*	☺	☺	☺	☺	☺	☺	☺	☺
Transitive-2obj *13 verbs*	☺	☺	☺	☺	☺	☺	☺	☺
Passivizable *24 verbs*	☺	😐	☺	☺	☺	☺	☺	☺

Things don't look so hard anymore (except for passivizable verbs for one strategy variant). That's probably the only one we would rule out.



Pearl & Sprouse in progress

Seven out of eight good variants

Learning strategy options

Syntax

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Pearl & Sprouse in progress

Seven out of eight good variants

Learning strategy options

How do we winnow this down?

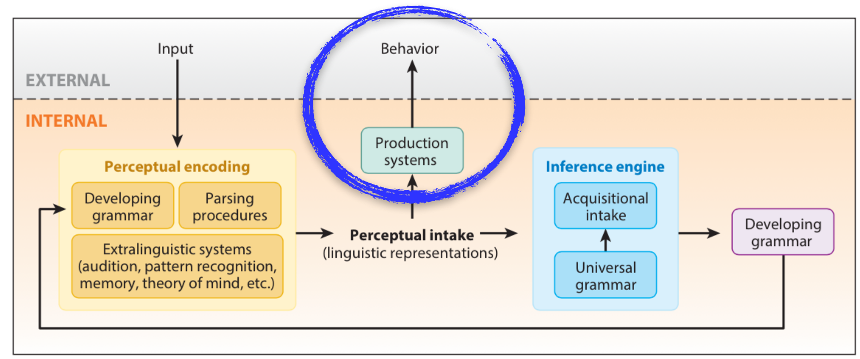
Pearl & Sprouse in progress

Seven out of eight good variants

Learning strategy options

How do we winnow this down?

Maybe we need more behavioral data about which specific verb distinctions children make at this age. This could then distinguish between these strategies.



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Pearl & Sprouse in progress

Seven out of eight good variants

Learning strategy options

How do we winnow this down?

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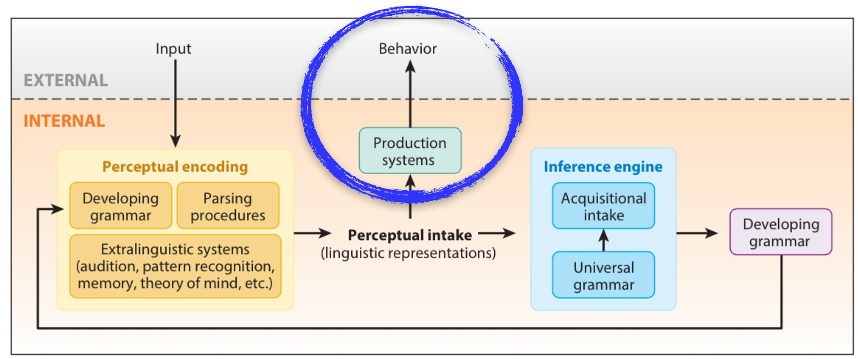
Example:
Verbs that are ditransitive and passivizable like *feed* and *give*



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Pearl & Sprouse in progress

Seven out of eight good variants

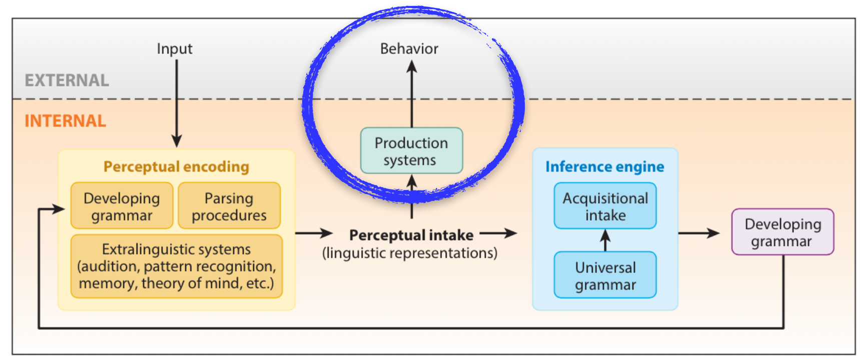
Learning strategy options

How do we winnow this down?

Maybe we need more behavioral data about which specific verb distinctions children make at this age. This could then distinguish between these strategies.

Example:
Verbs that are ditransitive and passivizable like *feed* and *give*

Do three-year-olds treat them the same?



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If yes, compatible with these:
+tense/aspect, rUTAH, +exp-mapping
+tense/aspect, rUTAH, -exp-mapping
-tense/aspect, UTAH, +exp-mapping
-tense/aspect, UTAH, -exp-mapping
-tense/aspect, rUTAH, +exp-mapping
-tense/aspect, rUTAH, -exp-mapping

NP V-ing NP

NP V NP

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

+exp-mapping:
movement is salient
because mapping to syntax is fixed

-exp-mapping:
syntax mapping distributions are tracked

If no, compatible with these:
+tense/aspect, UTAH, +exp-mapping
+tense/aspect, UTAH, -exp-mapping

NP V-ing NP

+exp-mapping:
movement is salient
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Pearl & Sprouse in progress

Learning strategy options

How do we winnow this down?

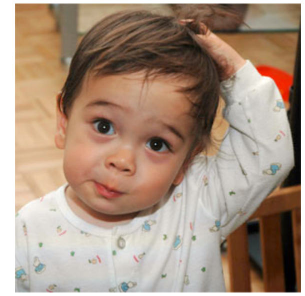
Near future:

Test these learners on a larger data set to combat potential data sparseness issues. (In progress: annotating the Brown-Adam corpus, which has about 20,000 more utterances.)

This also allows a larger age range of child-directed speech, extending up through age four. We can then investigate performance on predicate distinctions children make at later ages.

Pearl & Sprouse in progress

Learning strategy options



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Teaser: Even on these data directed at children under three, one strategy consistently does better at capturing the distinctions children will make at older ages.
(psych-subject experiencer verbs, psych-object experiencer verbs, raising-object verbs, raising-subject verbs, control-subject verbs, non-finite *to* complement verbs)
This is the same one that did better on *that*-complementizer verbs.

UTAH, +exp-mapping, -tense/aspect

+exp-mapping:
movement is salient
because mapping to syntax is fixed

NP V NP

Pearl & Sprouse in progress

What next?

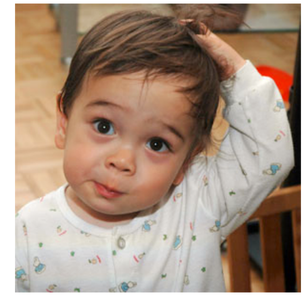
Further future:

Alternative theories: Are there other options for linking thematic role information to syntactic structure that we can explore in this framework? What about linking conceptual information, if we're not so sure thematic roles are there?

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

Pearl & Sprouse in progress

What next?



Further future:

More sophisticated syntactic cues: What kind of structure is necessary for children to know in order to capture some of the more sophisticated distinctions they make at later ages? (It's likely a simple syntactic skeleton won't be enough…)

She melted the ice —> NP V_{past} NP
The ice melted —> NP V_{past}
The ice was melted —> NP $V_{past\_participle}$
The ice was melting —> NP $V_{progressive\_participle}$

Pearl & Sprouse in progress

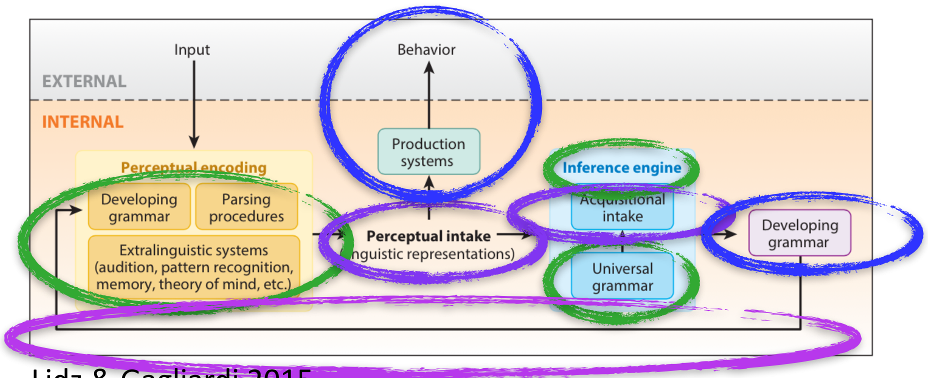
What next?

Further future:

More realistic assumptions about children:

- What if children only have some thematic roles available initially (and some syntactic structure), which they later build on? Do these theories still work/not work?

- What happens when we embed these theories in a learning model that learns incrementally (or at least in stages) and has cognitive constraints? For example, children might have one set of assumptions at age two, but a different set at age three based on the knowledge they've acquired.



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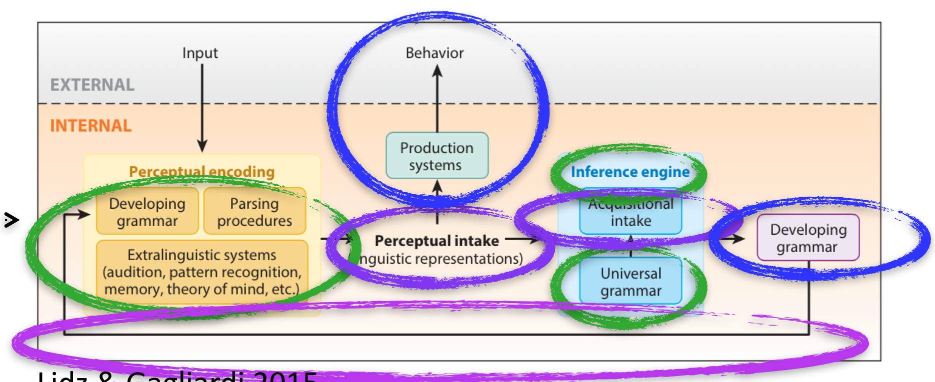
Pearl & Sprouse in progress

Big picture:
Understanding how children make syntactic generalizations

Precisely defining the components of a learning problem is necessary for making progress on how children solve that learning problem, which requires insights from many different empirical methods. This approach allows us to connect theories of linguistic representation and theories of language acquisition.

Given a specific initial state, a learner must use the data intake to reach the target state by the end of the learning period.



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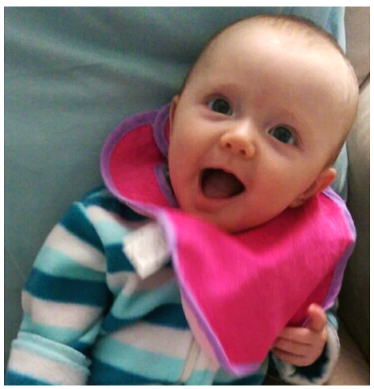
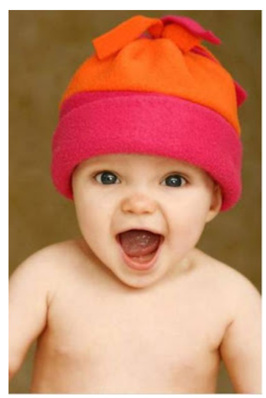
Biggest picture:
Computational acquisition modeling
for building integrated theories of acquisition

This technique is a useful tool — so let's use it to inform our theories of syntactic representation and acquisition!



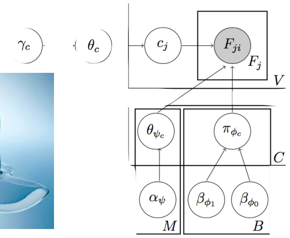



Thank you!

Jon Sprouse

McGill University

Linguistics 2016



done-to

The ice melted.

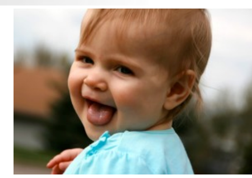
The penguin climbed.

doer

Agent > Experiencer >

Theme > Patient >

(Source, Goal, Instrument)



Computation of Language Laboratory

UC Irvine

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Special thanks to Abbie Thornton, Alandi Bates, Emily Yang, and BreAnna Silva for CHILDES Treebank corpus annotation.

Brown-Eve+Valian+Adam4yrs

Acquisitional intake: Input data

Brown-Eve+Valian+Adam4yrs

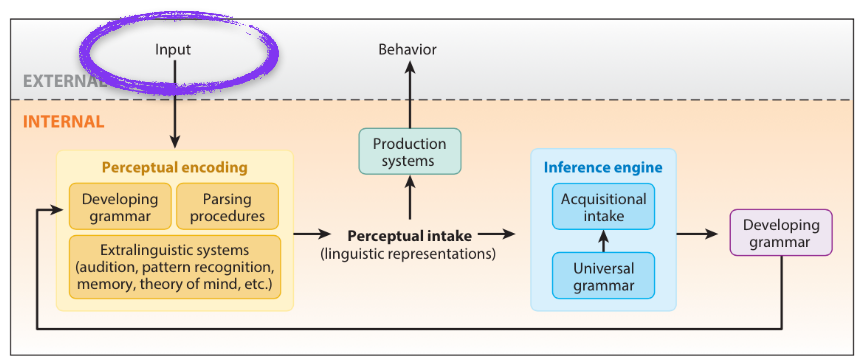
“it’s falling off”

Input

Data come from the Brown-Eve corpus (Brown 1973), the Valian corpus (Valian 1991), and the Brown-Adam corpus (Brown 1973) directed at age four, with syntactic & thematic annotations provided by the CHILDES Treebank (Pearl & Sprouse 2013).

This corpus (Brown-Eve+Valian+Adam4yrs) contains speech directed at 23 children between the ages of 18 and 58 months.

There are ~45,000 utterances total, comprised of ~224,000 word tokens. Of the 603 verb lexical items that appear, 253 occur 5 or more times.



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

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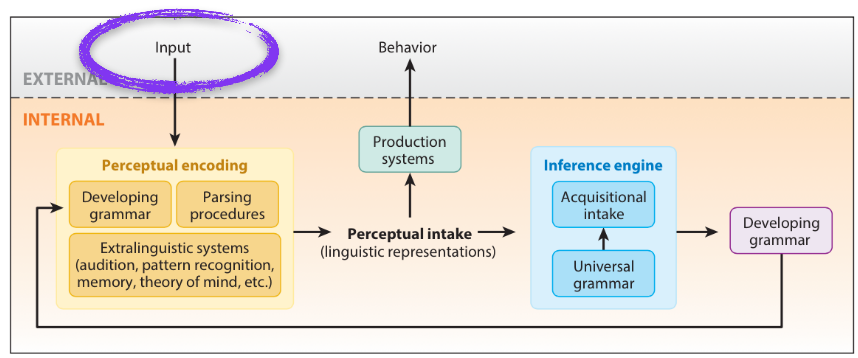
There are ~45,000 utterances total, comprised of ~224,000 word tokens. Of the 603 verb lexical items that appear, 253 occur 5 or more times.

Focus on learning the predicate categories for these for now.
Intuition: Frequent enough to be useful to distributionally learn from.



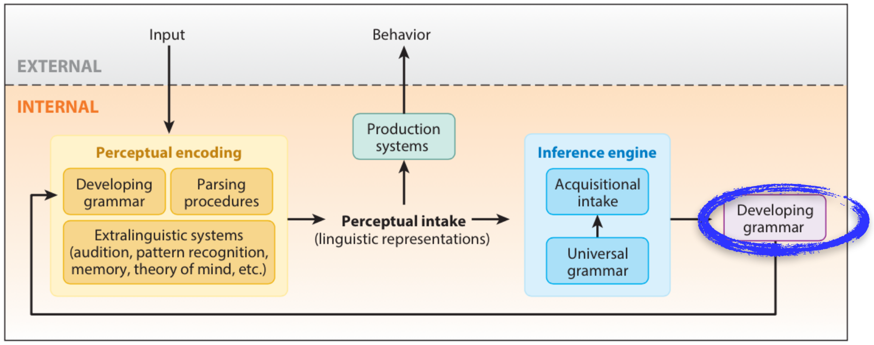
Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

Adult knowledge is the eventual target state for acquisition, and there are a variety of verb distinctions that have different syntactic and/or thematic role implications. Do some of these distinctions fall out directly by using the syntactic, conceptual, and semantic-syntactic cues we're using?

Given the input data we have from the Brown-Eve-Valian+Adam corpus (which is directed at children age 4;10 and younger), we can include distinctions children seem to have made by age five when we learn from those data.



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

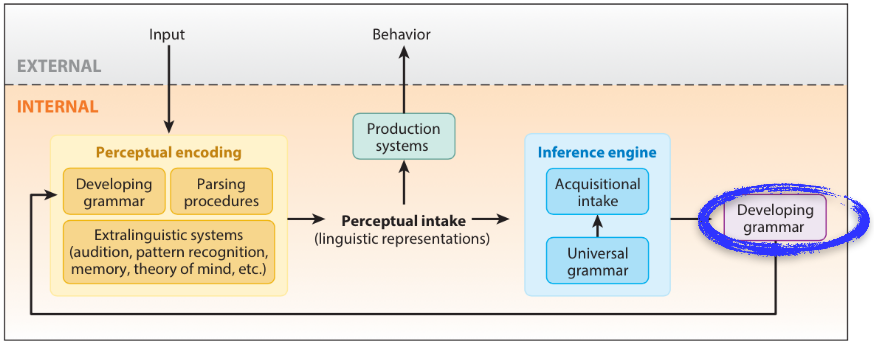
Children seem to figure out object-experiencer psych verbs before subject-experiencer psych verbs in English, though they seem to sort them both out by age 4 or 5 (Hartshorne, Pogue, & Snedeker 2015).

Psych, object experiencer "It ___ Jack."

Causer *Experiencer*

+= bother, confuse, scare, worry…

-= fall, go, kick, stare…



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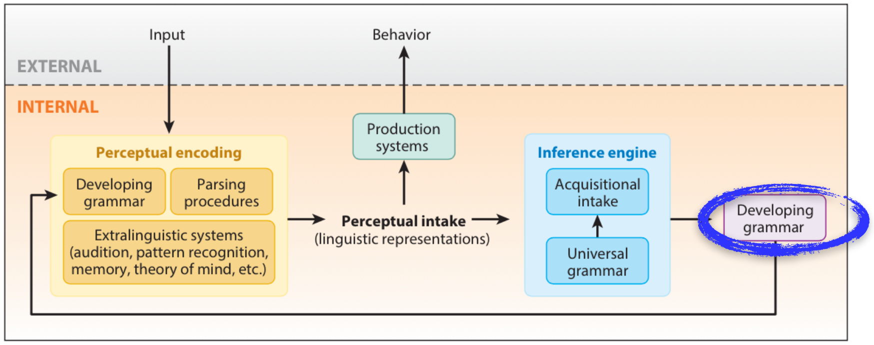
Psych, object experiencer "It ___ Jack."
Causer *Experiencer*

Psych, subject experiencer "Jack ___ it."
Experiencer *SubjectMatter*

+= like, love, miss, want…

-= fall, go, kick, stare…



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

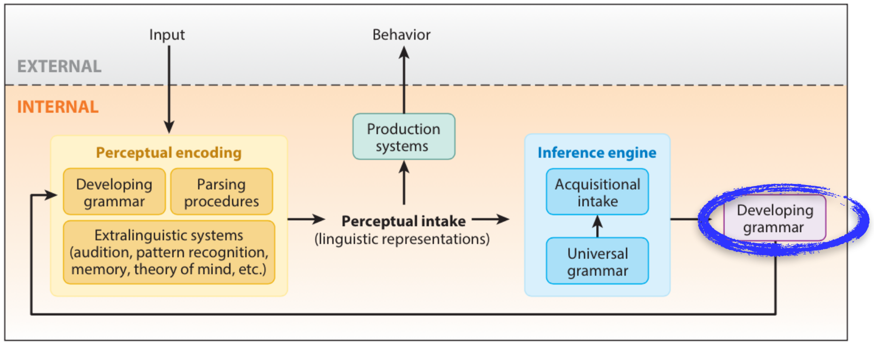
By 4 to 5 years old, English children can use animacy information when distinguishing between control-object and raising-object verbs (Kirby 2009, 2010, 2011).

Psych, object experiencer "It ___ Jack."
Causer *Experiencer*

Psych, subject experiencer "Jack ___ it."
Experiencer *SubjectMatter*

Control-object "Jack ___ her to win."
Agent-like
Goal-like

+= ask, tell, teach, thank…
-= fall, go, kick, stare…



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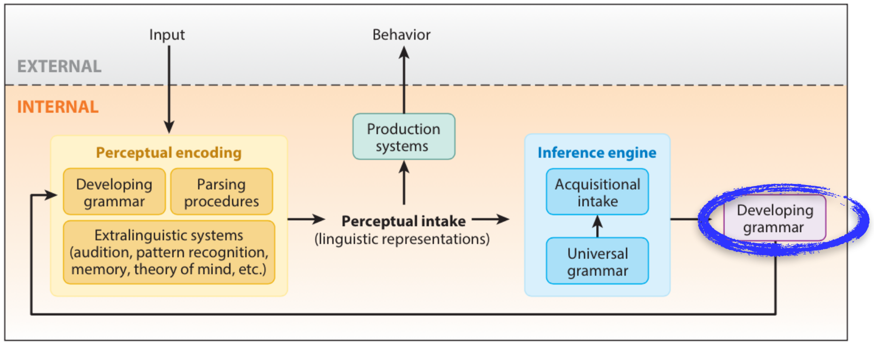
Psych, subject experiencer "Jack ___ it."
Experiencer *SubjectMatter*

Control-object "Jack ___ her to win."
Agent-like
Goal-like

Raising-object (ECM) "Jack ___ her to win."
Agent-like

+= knew, mean, need, take…
-= fall, go, kick, stare…



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Useful verb classes

By 4 to 5 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2006, 2007, 2009, 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Psych, object experiencer "It ___ Jack."
Causer *Experiencer*

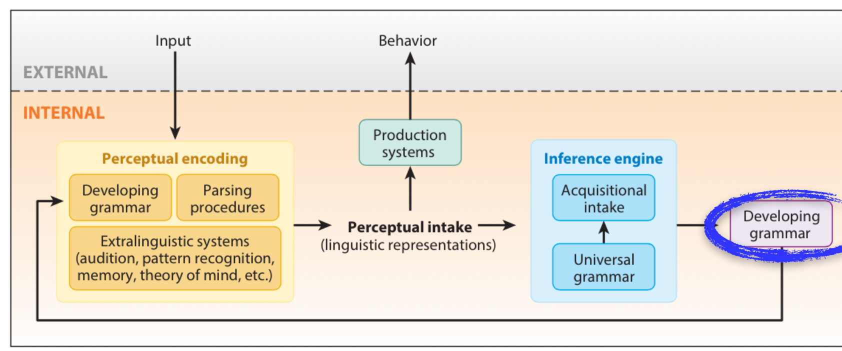
Psych, subject experiencer "Jack ___ it."
Experiencer *SubjectMatter*

Control-object "Jack ___ her to win."
Agent-like
Goal-like

Raising-object (ECM) "Jack ___ her to win."
Agent-like

Raising-subject "Jack ___ to win."
Agent-like

+= begin, happen, seem, use…
-= fall, go, kick, stare…



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Causer *Experiencer*

Psych, subject experiencer "Jack ___ it."
Experiencer *SubjectMatter*

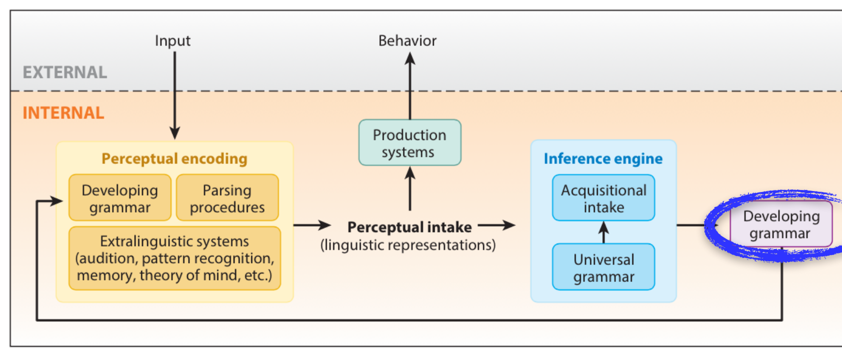
Control-object "Jack ___ her to win."
Agent-like
Goal-like

Raising-object (ECM) "Jack ___ her to win."
Agent-like

Raising-subject "Jack ___ to win."
Agent-like

Control-subject "Jack ___ to win."
Agent-like$_1$
Agent-like$_2$

+= decide, like, try, want…
-= fall, go, kick, stare…



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Target state: Useful verb classes

By 5 years old, English children use *whether/if*-complement taking verbs in their spontaneous speech (Diessel & Tomasello 2001), which may indicate they've formed a class of these verbs.

Psych, object experiencer "It ___ Jack."
Causer *Experiencer*

Psych, subject experiencer "Jack ___ it."
Experiencer *SubjectMatter*

Control-object "Jack ___ her to win."
Agent-like
Goal-like

Raising-object (ECM) "Jack ___ her to win."
Agent-like

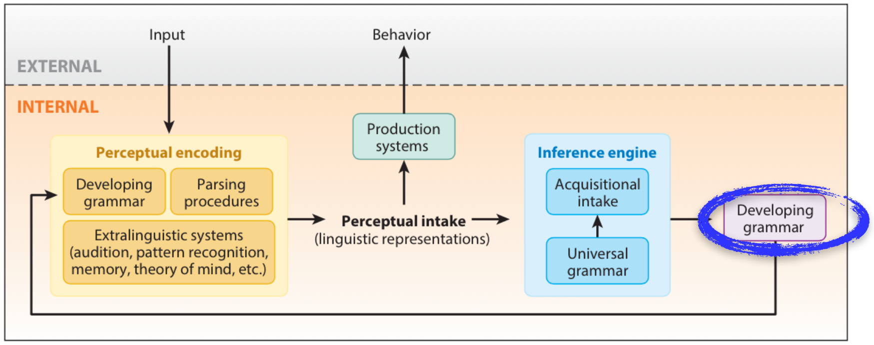
Raising-subject "Jack ___ to win."
Agent-like

Control-subject "Jack ___ to win."
Agent-like$_1$
Agent-like$_2$

whether/if-complement "Jack ___ whether we won."

+= decide, forget, know, wonder…

-= fall, go, kick, stare…



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Pearl & Sprouse in progress

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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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.*
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The penguin seemed to climb the hill.
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raising

Pearl & Sprouse in progress

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Agent-like = grammatical subject

Agent
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

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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

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

Agent-like = grammatical subject

Patient-like = grammatical object

Patient

Theme

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

Subject Matter

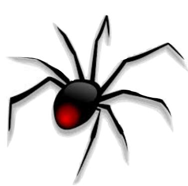
("external cause")

She fears spiders.

Experiencer

Spiders frighten her.

Experiencer



control

She tried to melt the ice.

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

**It tried that she melted the ice.*

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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
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…

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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)

control

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

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raising

Pearl & Sprouse in progress

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An example implementation:

Agent > Causer > Experiencer > Possessor >
Subject Matter > Causee > Theme > Patient >
(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

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doer — done-to

raising

Pearl & Sprouse in progress

Thematic roles & how to use them

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An example implementation:
Agent > Causer > Experiencer > Possessor >
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(Location, Source, Goal, Benefactor, Instrument)

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.

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

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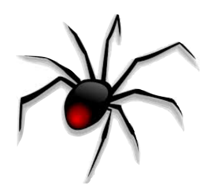
An example implementation:

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

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

What next?

Near-ish future:

Other ways to evaluate the output of the modeled learners.

(1) Qualitative analysis: Which verbs of each class is a learner consistently getting right? Are these more important/more useful in some respect? What do the errors look like, and do they look like the kind of thing children do? (Behavioral data on specific verbs gets at this somewhat already.)

(2) Utility of inferred classes: Can we identify a specific acquisition task that depends on verb classes, and see if the inferred classes are useful for that task (Phillips & Pearl 2015, Bar-Sever & Pearl 2016)? This can tell us if they're good classes, even if they don't match adult verb classes.

Pearl & Sprouse in progress

Learning strategy option refinement: The bigger picture

The Linking Problem: Pearl & Sprouse in progress

done-to

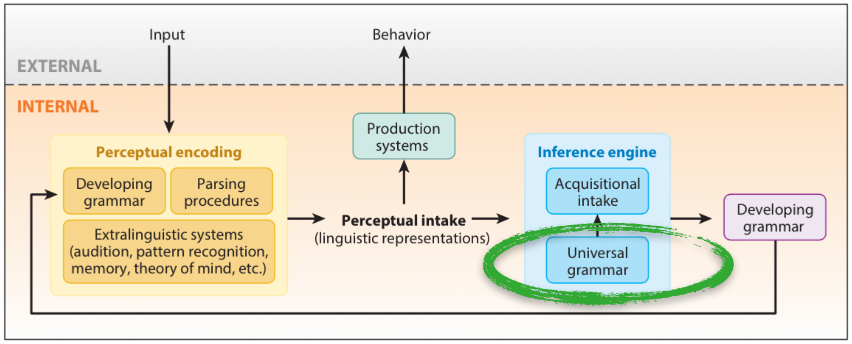
The ice melted.

The penguin climbed.

doer

Refining ideas about what implementations of prior knowledge are consistently useful for acquisition (Ambridge et al. 2014, Pearl 2014):

Not: UTAH & -exp-mapping if using surface tense/ aspect information



Lidz & Gagliardi 2015

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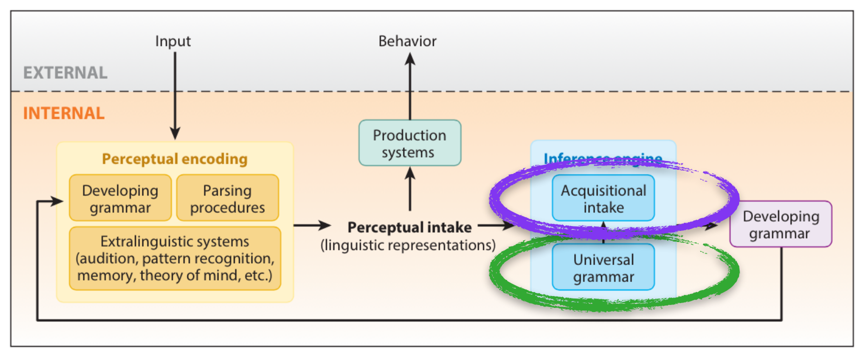

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Learning strategy option refinement: The bigger picture

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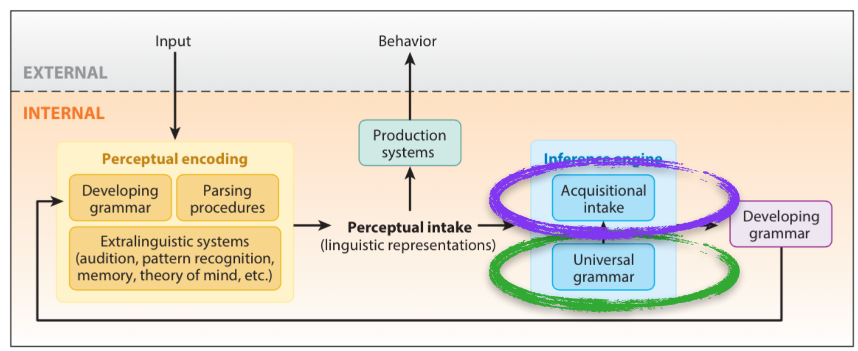
Larger point: Connection between theories of linguistic representation and theories of language acquisition



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