How to know what's necessary: Using computational modeling to specify Universal Grammar

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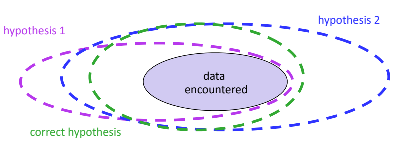
Motivating Universal Grammar

The argument from acquisition: one explicit motivation that highlights the natural link between linguistic representation and language acquisition.

Universal Grammar (UG) allows children to acquire knowledge about language as effectively and rapidly as they do (Chomsky 1980, Crain 1991, Hornstein & Lightfoot 1981, Lightfoot 1982b, Legate & Yang 2002, among many others).

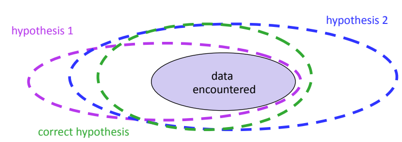
Motivating Universal Grammar

What's so hard about acquiring language?
There seem to be induction problems, given the available data.
(Poverty of the Stimulus, Logical Problem of Language Acquisition, Plato's Problem)



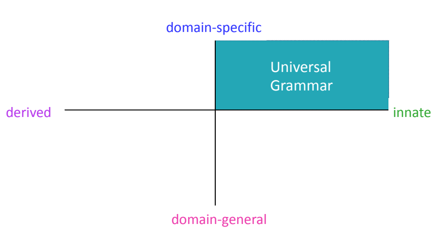
Motivating Universal Grammar

So if the data themselves don't pick out the right answer (and children all seem to), something internal to children must be guiding them.



Motivating Universal Grammar

If that something is both innate and domain-specific, we consider it part of Universal Grammar (UG) (Chomsky 1965, Chomsky 1975).



Motivating the contents of UG

Proposals have traditionally come from characterizing a specific acquisition problem for a particular linguistic phenomenon, and describing the (UG) solution to that specific characterization.

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Structure-dependent rules

(Chomsky 1980, Anderson & Lightfoot 2000; Fodor & Crowther 2002; Berwick et al. 2011; Anderson 2013)

Pirates who can dance can often fight well.

Can pirates who can dance __ often fight well?

Motivating the contents of UG

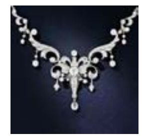
Proposals have traditionally come from characterizing a specific acquisition problem for a particular linguistic phenomenon, and describing the (UG) solution to that specific characterization.

Constraints on long-distance dependencies

(Chomsky 1973, Huang 1982, Lasnik & Saito 1984, Pearl & Sprouse 2013a, 2013b, 2015)

Where did Jack think Lily bought the necklace from __?

*Where did Jack think the necklace from __ was too expensive?



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Proposals have traditionally come from characterizing a specific acquisition problem for a particular linguistic phenomenon, and describing the (UG) solution to that specific characterization.

English anaphoric *one* representation

(Baker 1978, Pearl & Mis 2011, 2016)

Look – a red bottle! Do you see another *one*?

UG proposals: Generation & evaluation

How to generate a learning theory proposal:

Characterize the learning problem precisely and identify a potential solution.

UG proposals: Generation & evaluation

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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)

UG 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.

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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).

UG proposals: Generation & evaluation

How to generate a learning theory proposal:
Characterize the learning problem precisely and identify a potential solution.

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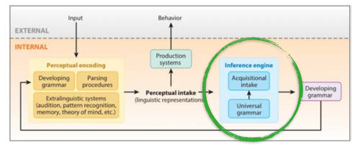
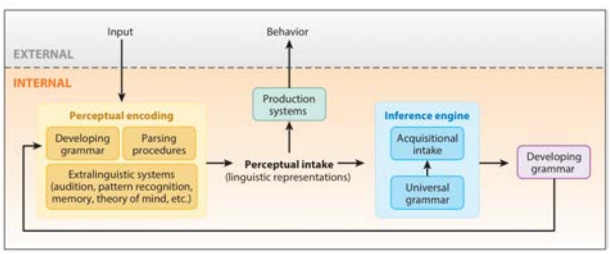
We've also seen the development of more sophisticated acquisition frameworks that highlight the precise role of UG (Lidz & Gagliardi 2015).



Example: UG determines what data from the perceived input are relevant (acquisitional intake)

The Lidz & Gagliardi (2015) acquisition framework



Lidz & Gagliardi 2015

UG 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 feedback helps us refine our theories about both the knowledge representation the learning theory relies on and the acquisition process that uses that representation.

UG 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.

How to decide if any components of the proposal are UG:
Examine the components of the successful learning solution.

UG 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.

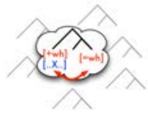
How to decide if any components of the proposal are UG:
Examine the components of the successful learning solution.

Are they necessarily both domain-specific and innate?

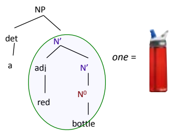
Note: We may use "innate" as a placeholder until we can determine if it's impossible to derive the relevant component (Pearl 2014, Pearl & Mis 2016).

UG proposal refinement: Recent successful forays

Syntactic islands (constraints on *wh*-dependencies):
Pearl & Sprouse 2013a, 2013b, 2015



English anaphoric *one*:
Pearl & Mis 2011, 2016



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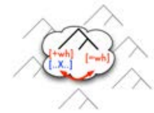

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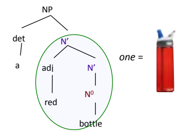
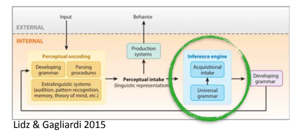


Recurring themes:

(1) Broadening the set of relevant data in the acquisitional intake



Lidz & Gagliardi 2015

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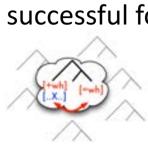

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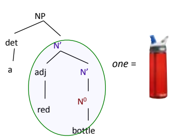
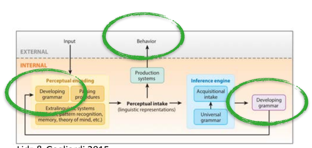


Recurring themes:

(1) Broadening the set of relevant data in the acquisitional intake

(2) Evaluating output by how useful it is



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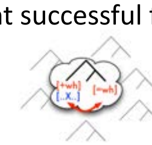

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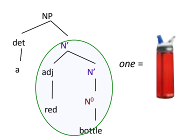
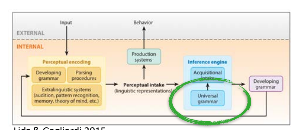


Recurring themes:

(1) Broadening the set of relevant data in the acquisitional intake

(2) Evaluating output by how useful it is

(3) Not necessarily needing the prior knowledge we thought we did



Lidz & Gagliardi 2015

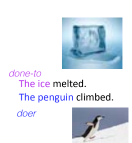
Today's Plan

Overview of how to characterize learning problems precisely enough

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

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

New modeling foray: The Linking Problem
(how and where event participants appear syntactically)



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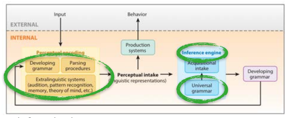
Characterizing learning problems

Initial state:



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Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

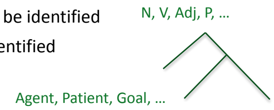
Initial state:

- initial knowledge state

ex: grammatical categories exist and can be identified

ex: phrase structure exists and can be identified

ex: participant roles can be identified



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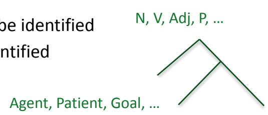
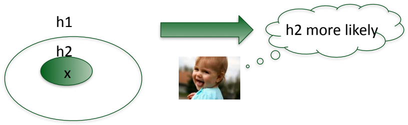


- learning biases & capabilities

ex: frequency information can be tracked

ex: distributional information can be leveraged

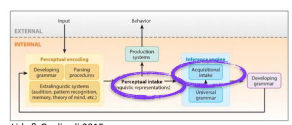


Pearl & Sprouse 2015, Pearl & Mis 2016

Characterizing learning problems

Initial state: initial knowledge state + learning biases & capabilities

Data intake:



Lidz & Gagliardi 2015

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Characterizing learning problems

Initial state: initial knowledge state + learning biases & capabilities

Data intake:

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

(Fodor 1998, Lidz & Gagliardi 2015)

ex: all *wh*-utterances for learning about *wh*-dependencies

ex: all pronoun data when learning about anaphoric *one*

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

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

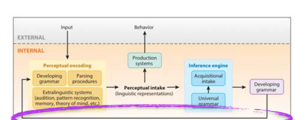
Pearl & Sprouse 2015, Pearl & Mis 2016

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

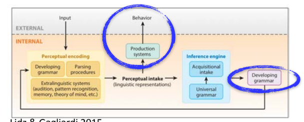
Characterizing learning problems

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:

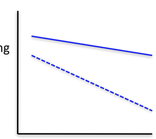
- the knowledge children are trying to attain (as indicated by their behavior)

ex: *Where did Jack think the necklace from __ was too expensive?
ex: *one* is category N' when it is not NP
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

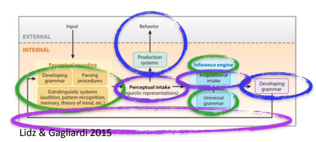
Initial state: initial knowledge state + learning biases & capabilities

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.



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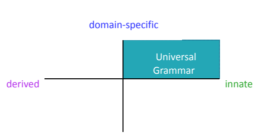
Informing UG (+ acquisition theory)

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

This identifies useful learning strategy components, which we can then examine to see where they might come from.

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



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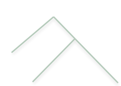

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What happened?
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New modeling foray: The Linking Problem
(how and where event participants appear syntactically)

done-to
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doer

The Linking Problem

- **Why**? About how conceptual information maps to syntactic structure, and tends to incorporate theoretical machinery 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.
The ice melted.
The ice was melted.

She tried to melt the ice.
*It tried that she melted the ice.

The penguin climbed the hill.
The penguin climbed.
The hill was climbed.

The penguin seemed to climb the hill.
It seemed that the penguin climbed the hill.

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.
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control

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raising

unergative

Pearl & Sprouse in progress

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The river froze.

??

unaccusative

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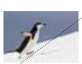

The penguin seemed to climb the hill.
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raising

unergative

Pearl & Sprouse in progress

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break crack close freeze

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raising

unergative

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

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raising

unergative

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

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unaccusative

control

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unergative

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

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doer
The hill was climbed.
done-to

unergative

Pearl & Sprouse in progress

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

The penguin climbed the hill.
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Pearl & Sprouse in progress

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unaccusative

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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

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doer done-to
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doer
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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

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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

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

unergative

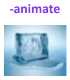
Pearl & Sprouse in progress

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 young children have been shown to use this cue in experimental studies (Becker 2009, Becker 2014, Becker 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

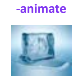
Pearl & Sprouse in progress

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

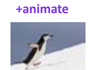


control

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

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

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

Syntax **She** melted **the ice** with **a blow dryer**.
Subject *Object* *Indirect Object*

Mapping to Syntax

UG knowledge

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

Syntax **She** melted **the ice** with **a blow dryer**.
Subject *Object* *Indirect Object*

Standard UTAH and rUTAH implementations typically assume this part is included.

Mapping to Syntax

UG knowledge

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

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

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

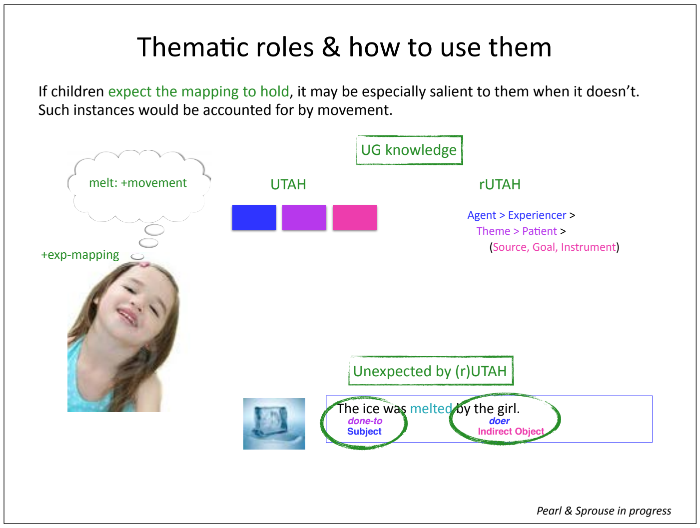
UTAH rUTAH

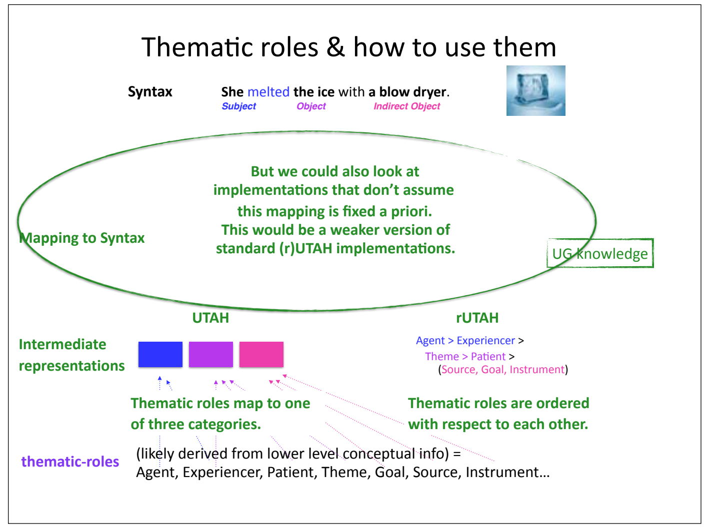
Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)

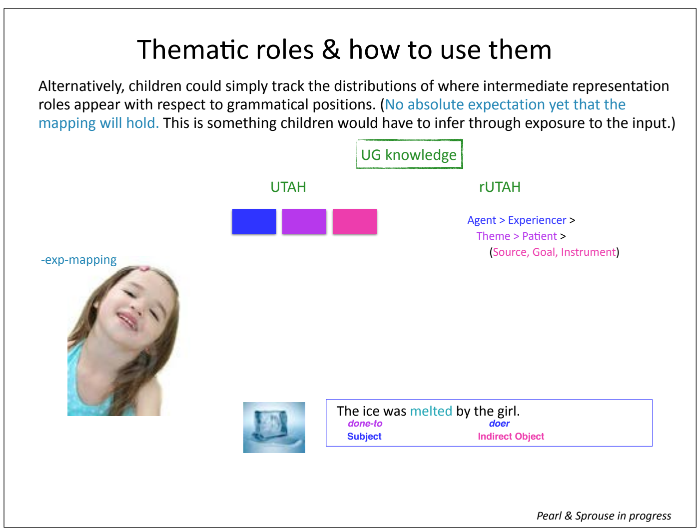
+exp-mapping

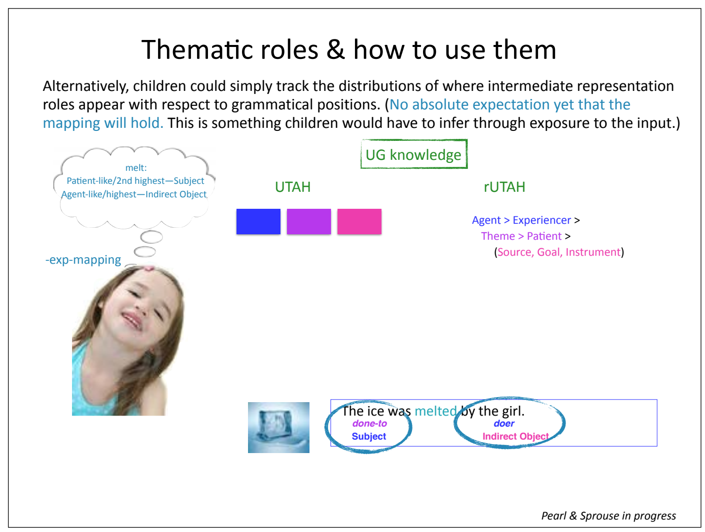
The ice was melted by the girl.
done-to *doer*
Subject Indirect Object

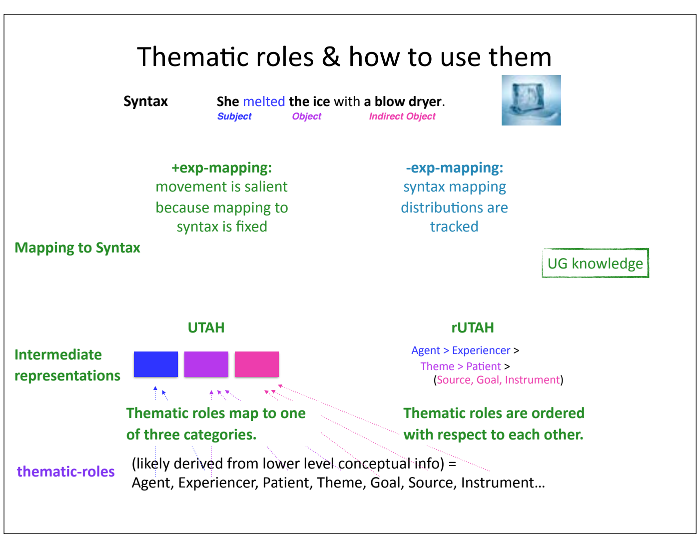
Pearl & Sprouse in progress

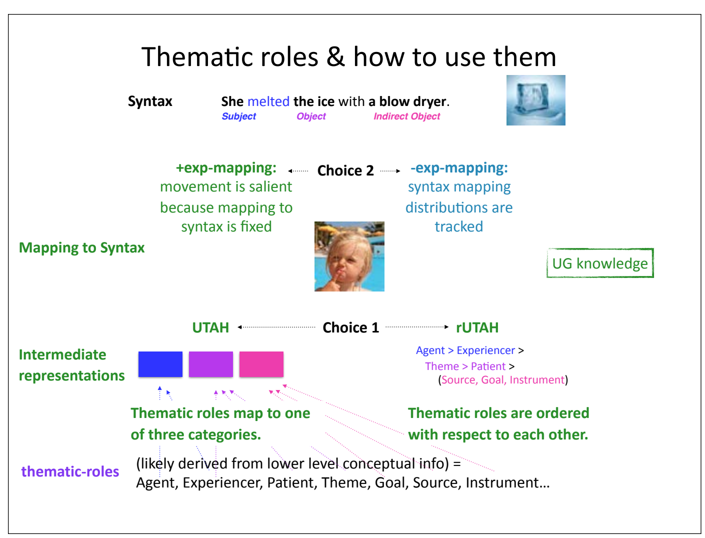

Thematic roles & how to use them
If children expect the mapping to hold, it may be especially salient to them when it doesn't.
Such instances would be accounted for by movement.
UG knowledge
melt: +movement
UTAH
rUTAH
Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)
+exp-mapping
Unexpected 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
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)
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
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
Subject
doer
Indirect Object
Pearl & Sprouse in progress


Thematic roles & how to use them
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
melt:
Patient-like/2nd highest—Subject
Agent-like/highest—Indirect Object
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
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
Intermediate representations
Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)
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
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
Intermediate representations
Agent > Experiencer >
Theme > Patient >
(Source, Goal, Instrument)
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…

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)

+ 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

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Potential learning strategies

UG knowledge options

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

+ some available tense and aspect information

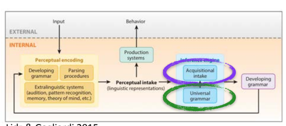
The ice was melted —> NP $V_{past\_participle}$

8 different 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



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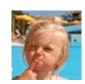
Learning strategy options

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) = Agent, Experiencer, Patient, Theme, Goal, Source, Instrument…

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 variants, which all cause different acquisitional intakes

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

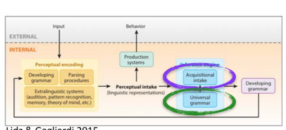
ignore available tense and aspect information

The ice was melted —> NP V

All learners are sensitive to the animacy of NPs.

-animate

+animate



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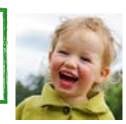
Initial state

The ability to identify and extract all relevant information reliably (syntactic + conceptual 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

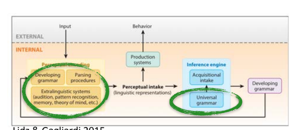
UTAH, -exp-mapping
UTAH, +exp-mapping
rUTAH, -exp-mapping
rUTAH, +exp-mapping

ignore available tense and aspect information

The ice was melted —> NP V

-animate

+animate



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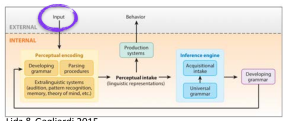
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

"it's falling off"

Input



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Pearl & Sprouse in progress

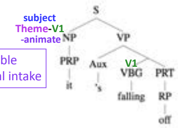
Acquisitional intake options

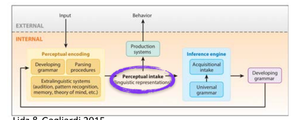
(from Brown-Eve corpus from CHILDES Treebank)

"it's falling off"

Input

Possible perceptual intake





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Pearl & Sprouse in progress

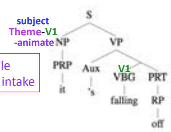
Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

"it's falling off"

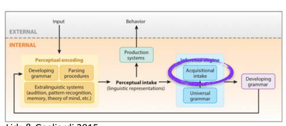
Input

Possible perceptual intake



Acquisitional intake

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



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Pearl & Sprouse in progress

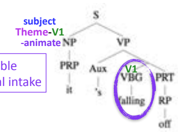
Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

"it's falling off"

Input

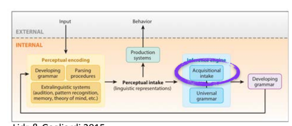
Possible perceptual intake



Acquisitional intake

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

FALL



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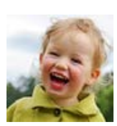
Pearl & Sprouse in progress

Acquisitional intake options

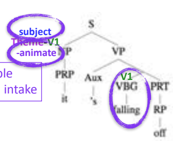
(from Brown-Eve corpus from CHILDES Treebank)



"it's falling off"

Input

Possible perceptual intake

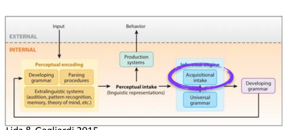


Acquisitional intake

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

FALL

-animate subject: 1



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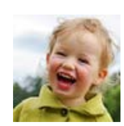
Pearl & Sprouse in progress

Acquisitional intake options

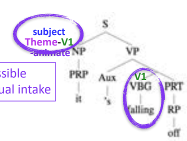
(from Brown-Eve corpus from CHILDES Treebank)



"it's falling off"

Input

Possible perceptual intake



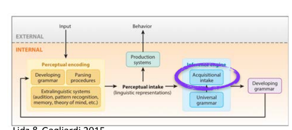
Acquisitional intake

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

FALL

-animate subject: 1

Patient-like as subject: 1



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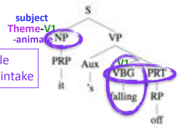
Acquisitional intake options

(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

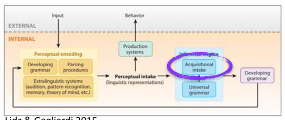
FALL

-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)



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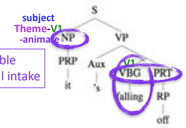
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



"it's falling off"

Input

Possible perceptual intake

Acquisitional intake

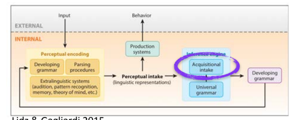
(2) UTAH, -exp-mapping,-some available tense and aspect information

FALL

-animate subject: 1

Patient-like as subject: 1

NP V PRT



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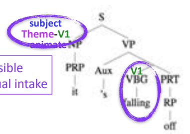
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

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



"it's falling off"

Input

Possible perceptual intake

Acquisitional intake

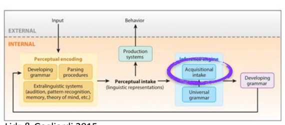
(3) UTAH, +exp-mapping,-some available tense and aspect information

FALL

-animate subject: 1

+movement: 1

NP V PRT



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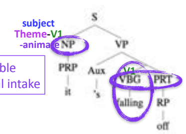
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)



"it's falling off"

Input

Possible perceptual intake

Acquisitional intake

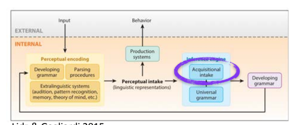
(4) UTAH, +exp-mapping,+some available tense and aspect information

FALL

-animate subject: 1

+movement: 1

NP $V_{present\_participle}$ PRT



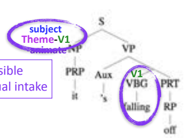
Lidz & Gagliardi 2015

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).



"it's falling off"

Input

Possible perceptual intake

Acquisitional intake

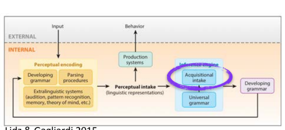
(5) rUTAH, +exp-mapping,+some available tense and aspect information

FALL

-animate subject: 1

+movement: 0

NP $V_{present\_participle}$ PRT



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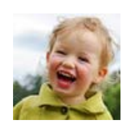
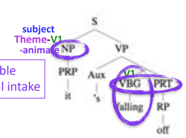
Pearl & Sprouse in progress

Acquisitional intake options



(from Brown-Eve corpus from CHILDES Treebank)



"it's falling off"

Input

Possible perceptual intake

Acquisitional intake

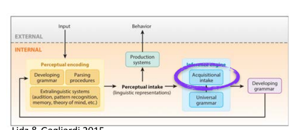
(6) rUTAH, +exp-mapping,-some available tense and aspect information

FALL

-animate subject: 1

+movement: 0

NP V PRT



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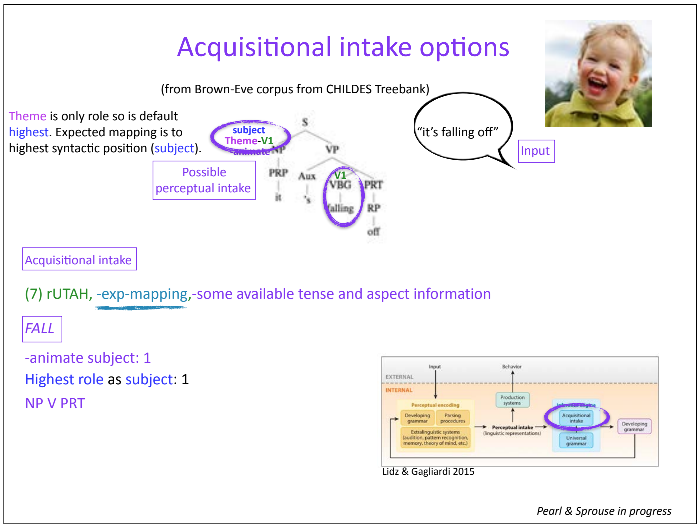
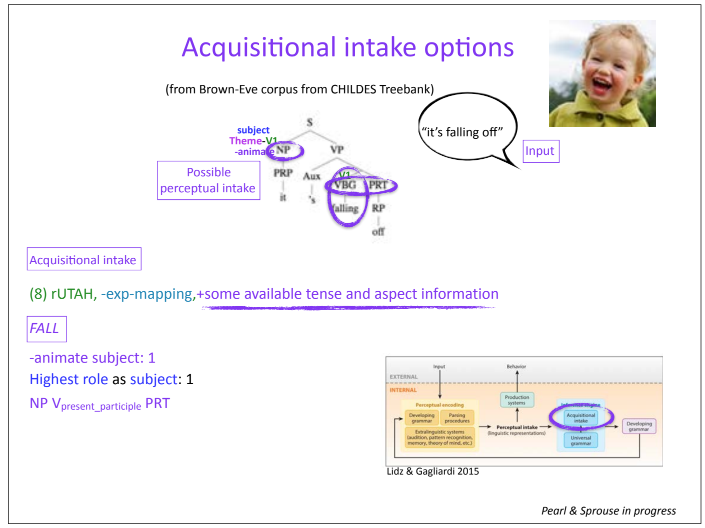
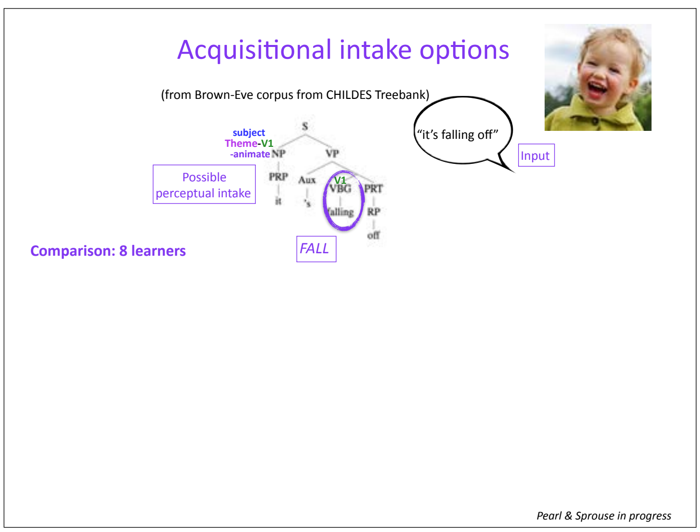
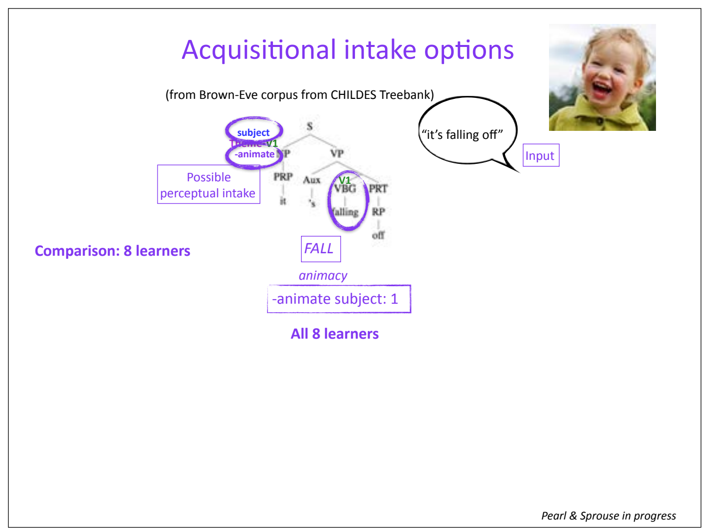
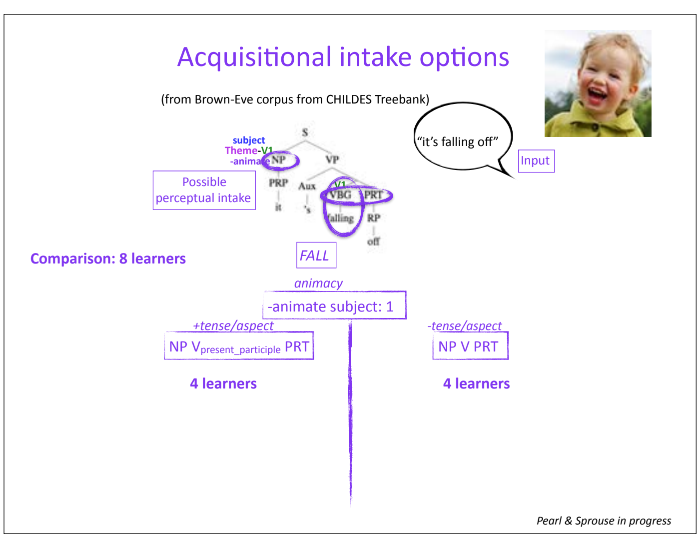
Pearl & Sprouse in progress

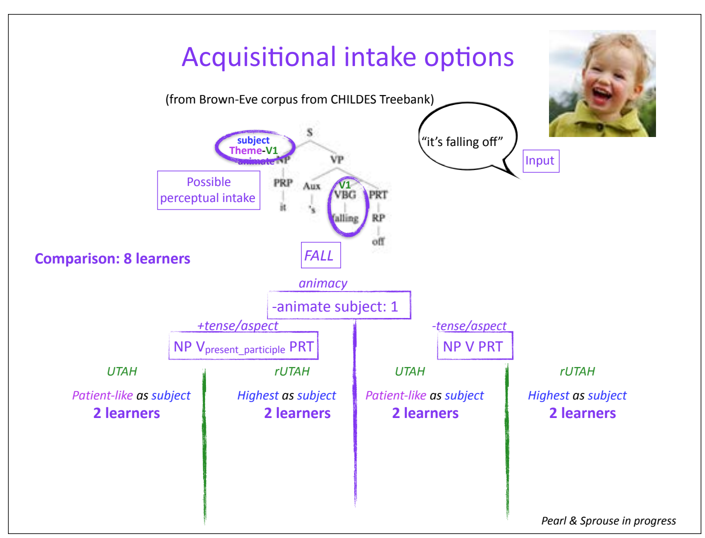

Acquisitional intake options
(from Brown-Eve corpus from CHILDES Treebank)
Theme is only role so is default highest. Expected mapping is to highest syntactic position (subject).
subject
Theme-V1
-animate
"it's falling off"
Input
Possible perceptual intake
S
NP
VP
PRP
Aux
V1
VBG
PRT
it
's
falling
RP
off
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)
subject
Theme-V1
-animate
"it's falling off"
Input
Possible perceptual intake
S
NP
VP
PRP
Aux
V1
VBG
PRT
it
's
falling
RP
off
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
Lidz & Gagliardi 2015
Pearl & Sprouse in progress


Acquisitional intake options
(from Brown-Eve corpus from CHILDES Treebank)
subject
Theme-V1
-animate
"it's falling off"
Input
Possible perceptual intake
S
NP
VP
PRP
Aux
V1
VBG
PRT
it
's
falling
RP
off
Comparison: 8 learners
FALL
Pearl & Sprouse in progress


Acquisitional intake options
(from Brown-Eve corpus from CHILDES Treebank)
subject
Theme-V1
-animate
"it's falling off"
Input
Possible perceptual intake
Comparison: 8 learners
FALL
animacy
-animate subject: 1
All 8 learners
Pearl & Sprouse in progress

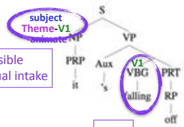

Acquisitional intake options
(from Brown-Eve corpus from CHILDES Treebank)
subject
Theme-V1
-animate
"it's falling off"
Input
Possible perceptual intake
Comparison: 8 learners
FALL
animacy
-animate subject: 1
+tense/aspect
NP V_present_participle PRT
4 learners
-tense/aspect
NP V PRT
4 learners
Pearl & Sprouse in progress


Acquisitional intake options
(from Brown-Eve corpus from CHILDES Treebank)
subject
Theme-V1
-animate
"it's falling off"
Input
Possible perceptual intake
Comparison: 8 learners
FALL
animacy
-animate subject: 1
+tense/aspect
NP V_present_participle PRT
-tense/aspect
NP V PRT
UTAH
Patient-like as subject
2 learners
rUTAH
Highest as subject
2 learners
UTAH
Patient-like as subject
2 learners
rUTAH
Highest as subject
2 learners
Pearl & Sprouse in progress

Acquisitional intake options

(from Brown-Eve corpus from CHILDES Treebank)

"it's falling off" Input



Possible perceptual intake

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*	
+exp-mapping	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
+movement: 1	Patient-like as subject: 1	+movement: 0	Highest as subject: 1	+movement: 1	Patient-like as subject: 1	+movement: 0	Highest as subject: 1
1 learner	**1 learner**	**1 learner**	**1 learner**	**1 learner**	**1 learner**	**1 learner**	**1 learner**

Pearl & Sprouse in progress

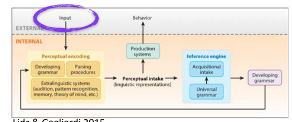
Acquisitional intake: Input data

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

"it's falling off" Input

This corpus contains speech directed at one child between the ages of 18 and 27 months.

There are 14,246 utterances total, comprised of 63,267 word tokens. Of the 289 verb lexical items that appear, 102 occur 10 or more times.



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Acquisitional intake: Input data

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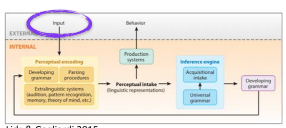
"it's falling off" Input

This corpus contains speech directed at one child between the ages of 18 and 27 months.

There are 14,246 utterances total, comprised of 63,267 word tokens. Of the 289 verb lexical items that appear, 102 occur 10 or more times.

Focus on learning the predicate categories for these for now.

Intuition: Frequent enough to be useful to distributionally learn from.

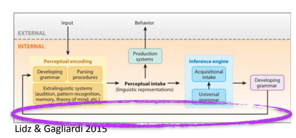


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

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?



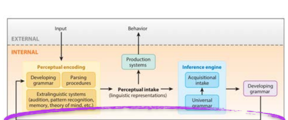
Lidz & Gagliardi 2015

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?

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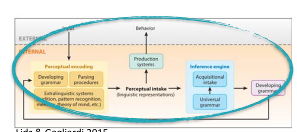


Lidz & Gagliardi 2015

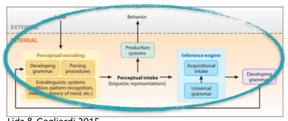
Pearl & Sprouse in progress

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

Even more

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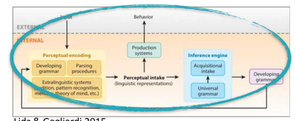
This kind of analysis is very helpful for determining if this implementation of the acquisition task is the right one. In particular, if children are sensitive to this information in the perceptual intake, is that enough to yield the target knowledge/behavior? Are these useful learning assumptions for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



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

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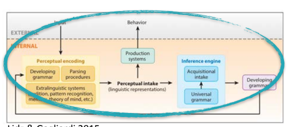
This is typically implemented as an ideal learner model, which isn't concerned with the cognitive limitations and incremental learning restrictions children have.

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



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

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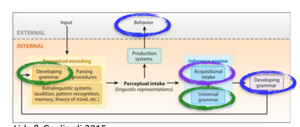
So, for an ideal learner, learning period considerations aren't as important as considerations about the initial state, data intake, and target knowledge/behavior.



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

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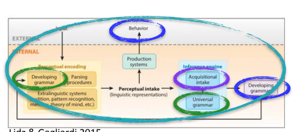
Practical note: Doing a computational analysis is often a really good idea to make sure we've got the right conceptualization of the acquisition task (see Pearl 2011 for the trouble you can get into when you don't do this first).



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning period

Even more

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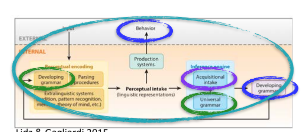
So, that's why we're going to start with a computational-level model of the acquisition process.



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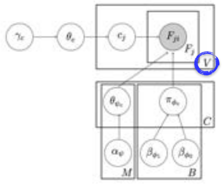
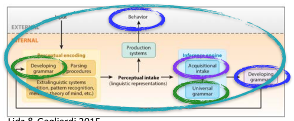
Learning process: Computational-level



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

FALL



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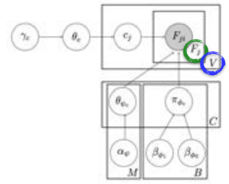
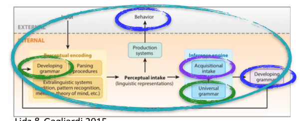
Learning process: Computational-level



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?"



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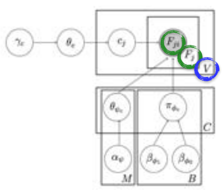
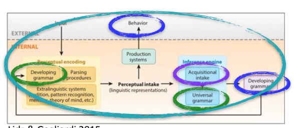
Learning process: Computational-level



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?"



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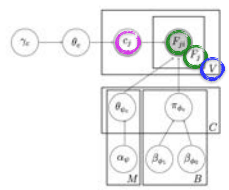
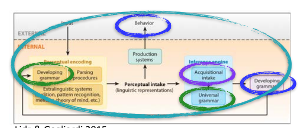
Learning process: Computational-level



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?"

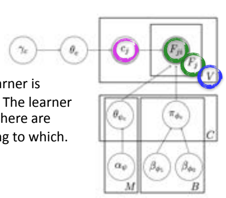


Lidz & Gagliardi 2015

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.



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(3x) "it's falling off"
"she fell down"
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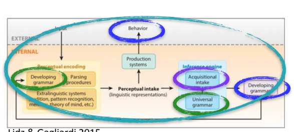

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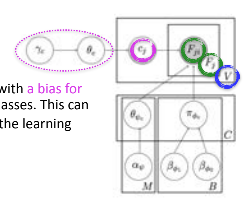
Pearl & Sprouse in progress

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.



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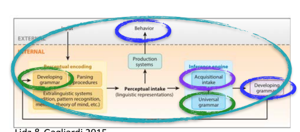
FALL *unaccusatives*

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



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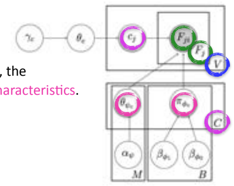
Pearl & Sprouse in progress

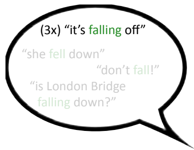
Learning process: Computational-level

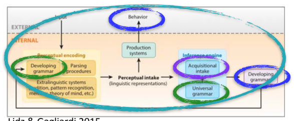
Depending on the class of the verb, the observed usage will have certain characteristics.



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

FALL *unaccusatives*





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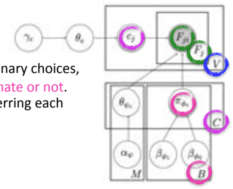
Pearl & Sprouse in progress

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.



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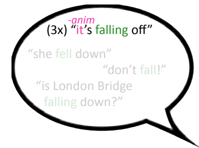
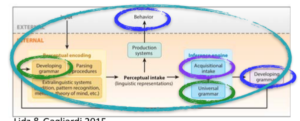
FALL *unaccusatives*





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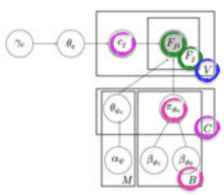
Pearl & Sprouse in progress

Learning process: Computational-level

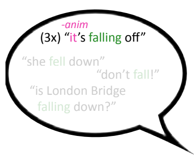
Binary properties include:

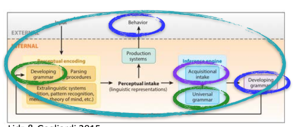
+/-animate subject
+/-animate object
+/-animate indirect object
+/-movement (when +exp-mapping)



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

FALL *unaccusatives*



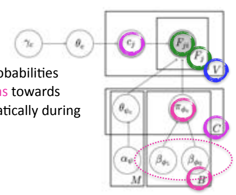


Lidz & Gagliardi 2015

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.



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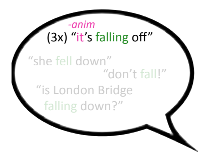

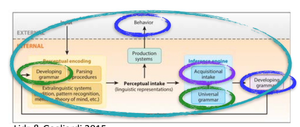

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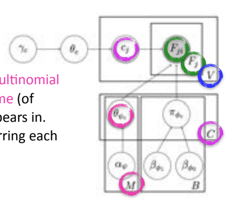
Pearl & Sprouse in progress

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.



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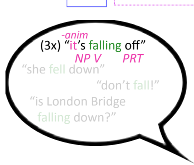

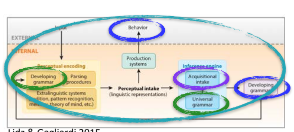

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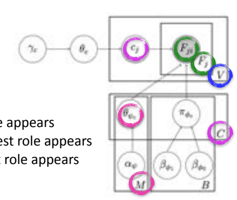
Pearl & Sprouse in progress

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



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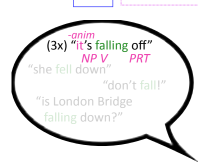
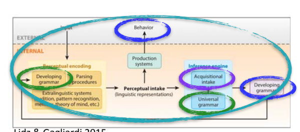
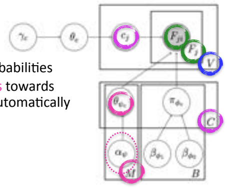




Lidz & Gagliardi 2015

Pearl & Sprouse in progress

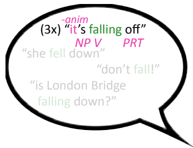
Learning process: Computational-level

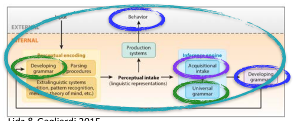


The learner doesn't know these probabilities beforehand, and begins with no bias towards any of them. This can be adjusted automatically during the learning process.

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

FALL | unaccusatives





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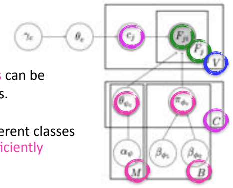
Pearl & Sprouse in progress

Learning process: Computational-level

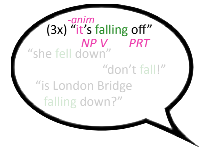


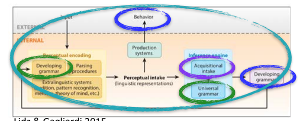
All the characteristics for each class can be inferred during the learning process.

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





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Pearl & Sprouse in progress

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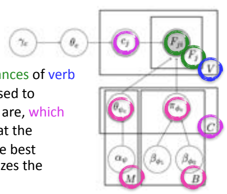
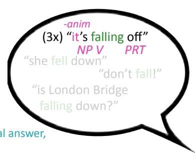


Summary: Using the observed instances of verb usage, Bayesian inference can be used to determine how many classes there are, which class each verb belongs to, and what the characteristics are of each class. The best answer will be the one that maximizes the probability of the observed data.

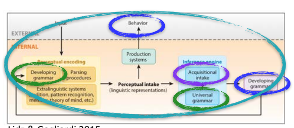
Each verb belongs to some class which determines its linguistic behavior.

FALL | unaccusatives



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

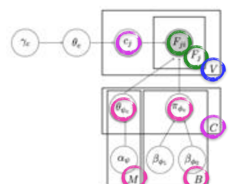
+ Gibbs sampling (method guaranteed to find optimal answer, given sufficient time to search the hypothesis space)



Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Learning process: Computational-level



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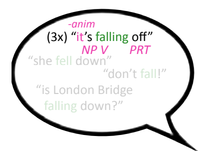
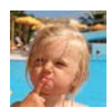
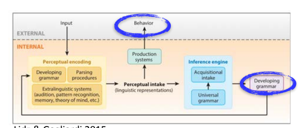
FALL | unaccusatives





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



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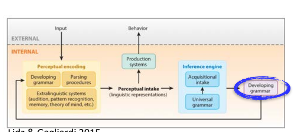
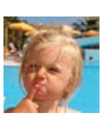
Pearl & Sprouse in progress

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 conceptual and syntactic cues we're using?



Lidz & Gagliardi 2015



Pearl & Sprouse in progress

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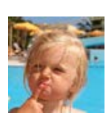
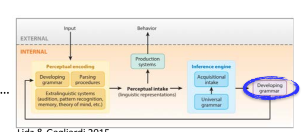
Transitive, single object "Jack ___ it."



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

-= cough, laugh, sleep, sneeze, …



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Pearl & Sprouse in progress

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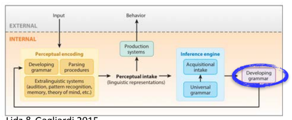
Transitive, single object "Jack ___ it."

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

+= allow, bring, pour, send, ...

-= bite, eat, laugh, sleep, understand...



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Pearl & Sprouse in progress

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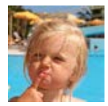
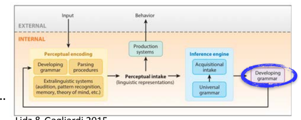
Psych, subject experiencer "Jack ___ it." *Experiencer SubjectMatter*



+= love, miss

-= bite, eat, laugh, sleep, understand...



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Pearl & Sprouse in progress

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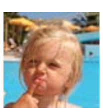
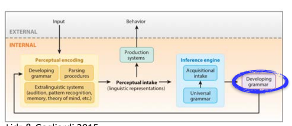


+= bother, surprise, worry, ...

-= bite, eat, laugh, sleep, understand...



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Pearl & Sprouse in progress

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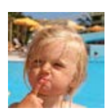
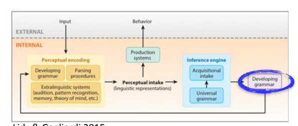
Unergative "Jack ___." *Agent-like*



+= cry, dance, listen, play,...

-= bounce, follow, push, shake,...



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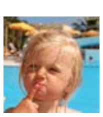
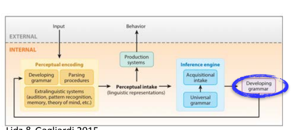


+= bounce, break, freeze, melt,...

-= call, find, help, see,...



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Pearl & Sprouse in progress

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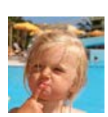
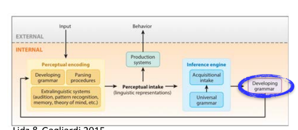
Passivizable "It was ___-en." *Patient-like*



+= answer, bounce, melt, open...

-= fall, go, happen, stare...



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Pearl & Sprouse in progress

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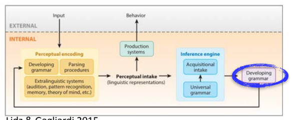
Unergative	"Jack ___." *Agent-like*
Unaccusative	"Jack ___." *Patient-like*
Passivizable	"It was ___-en." *Patient-like*
Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*



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+= allow, like, love, understand…
-= fall, go, happen, stare…

Pearl & Sprouse in progress

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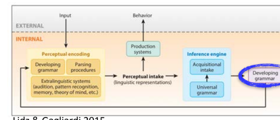
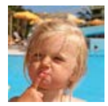
Control-object	"Jack ___ her to win." *Agent-like Goal-like*



Lidz & Gagliardi 2015



+= ask, name, pick, tell…
-= fall, go, happen, stare…

Pearl & Sprouse in progress

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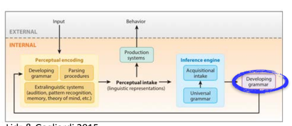
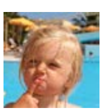
Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Control-subject	"Jack ___ to win." *Agent-like$_1$ Agent-like$_2$*



Lidz & Gagliardi 2015



+= ask, forget, try, want…
-= fall, go, happen, stare…

Pearl & Sprouse in progress

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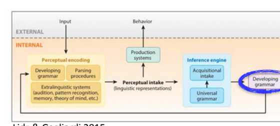
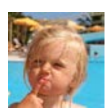


Lidz & Gagliardi 2015



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

Pearl & Sprouse in progress

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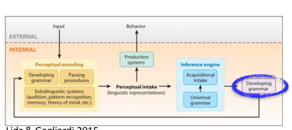
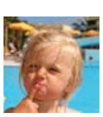
Psych, object experiencer	"It ___ Jack." *Causer Experiencer*
Unergative	"Jack ___." *Agent-like*
Unaccusative	"Jack ___." *Patient-like*
Passivizable	"It was ___-en." *Patient-like*
Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*
Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Control-subject	"Jack ___ to win." *Agent-like$_1$ Agent-like$_2$*
Raising-subject	"Jack ___ to win." *Agent-like*
that-complement	"Jack ___ that we won."



Lidz & Gagliardi 2015



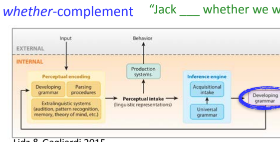
+= care, hope, insist, wish…
-= fall, go, kick, stare…

Pearl & Sprouse in progress

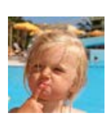
Target state: Useful verb classes

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 conceptual and syntactic cues we're using?

Verb class	Frame
Transitive, single object	"Jack ___ it."
Transitive, double object	"Jack ___ Lily the thing."
Psych, subject experiencer	"Jack ___ it." *Experiencer SubjectMatter*
Psych, object experiencer	"It ___ Jack." *Causer Experiencer*
Unergative	"Jack ___." *Agent-like*
Unaccusative	"Jack ___." *Patient-like*
Passivizable	"It was ___-en." *Patient-like*
Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*
Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Control-subject	"Jack ___ to win." *Agent-like$_1$ Agent-like$_2$*
Raising-subject	"Jack ___ to win." *Agent-like*
that-complement	"Jack ___ that we won."
whether-complement	"Jack ___ whether we won."



Lidz & Gagliardi 2015



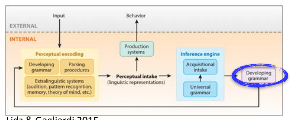
+= check, forget, tell, wonder…
-= fall, go, kick, stare…

Pearl & Sprouse in progress

Target state: Children's developing representations

Also, it may well be that some of these distinctions are more salient to children than others.

Transitive, single object	"Jack ___ it."	Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*
Transitive, double object	"Jack ___ Lily the thing."	Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Psych, subject experiencer	"Jack ___ it." *Experiencer SubjectMatter*	Control-subject	"Jack ___ to win." *Agent-like₁ Agent-like₂*
Psych, object experiencer	"It ___ Jack." *Causer Experiencer*	Raising-subject	"Jack ___ to win." *Agent-like*
Unergative	"Jack ___." *Agent-like*	*that*-complement	"Jack ___ that we won."
Unaccusative	"Jack ___." *Patient-like*	*whether*-complement	"Jack ___ whether we won."
Passivizable	"It was ___-en." *Patient-like*		



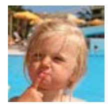
Lidz & Gagliardi 2015

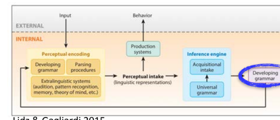
Pearl & Sprouse in progress

Target state: Children's developing representations

Transitives (with a single object) seem to be recognized as early as 28 months old in English: Yuan & Fisher 2009, Scott & Fisher 2009.

Transitive, single object	"Jack ___ it."	Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*
Transitive, double object	"Jack ___ Lily the thing."	Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Psych, subject experiencer	"Jack ___ it." *Experiencer SubjectMatter*	Control-subject	"Jack ___ to win." *Agent-like₁ Agent-like₂*
Psych, object experiencer	"It ___ Jack." *Causer Experiencer*	Raising-subject	"Jack ___ to win." *Agent-like*
Unergative	"Jack ___." *Agent-like*	*that*-complement	"Jack ___ that we won."
Unaccusative	"Jack ___." *Patient-like*	*whether*-complement	"Jack ___ whether we won."
Passivizable	"It was ___-en." *Patient-like*		





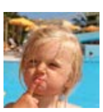
Lidz & Gagliardi 2015

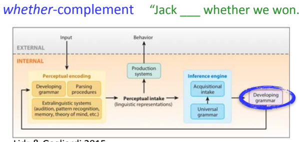
Pearl & Sprouse in progress

Target state: Children's developing representations

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old

Transitive, single object	"Jack ___ it."	Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*
Transitive, double object	"Jack ___ Lily the thing."	Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Psych, subject experiencer	"Jack ___ it." *Experiencer SubjectMatter*	Control-subject	"Jack ___ to win." *Agent-like₁ Agent-like₂*
Psych, object experiencer	"It ___ Jack." *Causer Experiencer*	Raising-subject	"Jack ___ to win." *Agent-like*
Unergative	"Jack ___." *Agent-like*	*that*-complement	"Jack ___ that we won."
Unaccusative	"Jack ___." *Patient-like*	*whether*-complement	"Jack ___ whether we won."
Passivizable	"It was ___-en." *Patient-like*		





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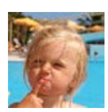
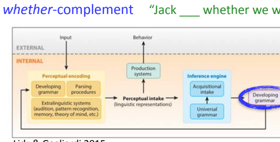
Pearl & Sprouse in progress

Target state: Children's developing representations

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Transitive, single object	"Jack ___ it."	Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*
Transitive, double object	"Jack ___ Lily the thing."	Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Psych, subject experiencer	"Jack ___ it." *Experiencer SubjectMatter*	Control-subject	"Jack ___ to win." *Agent-like₁ Agent-like₂*
Psych, object experiencer	"It ___ Jack." *Causer Experiencer*	Raising-subject	"Jack ___ to win." *Agent-like*
Unergative	"Jack ___." *Agent-like*	*that*-complement	"Jack ___ that we won."
Unaccusative	"Jack ___." *Patient-like*	*whether*-complement	"Jack ___ whether we won."
Passivizable	"It was ___-en." *Patient-like*		





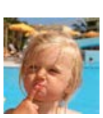
Lidz & Gagliardi 2015

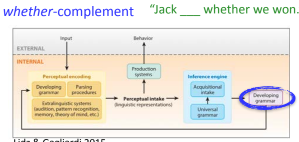
Pearl & Sprouse in progress

Target state: Children's developing representations

Passives seem to be used appropriately by 4 years old (with the correct structural features available by 3 years old): Crain, Thornton & Murasugi, 1987, Budwig 1990, Tomasello, Brooks, & Stern 1998, Huttenlocher et al. 2004.

Transitive, single object	"Jack ___ it."	Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*
Transitive, double object	"Jack ___ Lily the thing."	Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Psych, subject experiencer	"Jack ___ it." *Experiencer SubjectMatter*	Control-subject	"Jack ___ to win." *Agent-like₁ Agent-like₂*
Psych, object experiencer	"It ___ Jack." *Causer Experiencer*	Raising-subject	"Jack ___ to win." *Agent-like*
Unergative	"Jack ___." *Agent-like*	*that*-complement	"Jack ___ that we won."
Unaccusative	"Jack ___." *Patient-like*	*whether*-complement	"Jack ___ whether we won."
Passivizable	"It was ___-en." *Patient-like*		





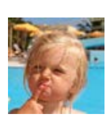
Lidz & Gagliardi 2015

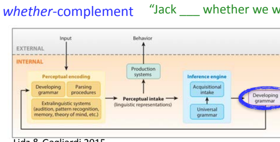
Pearl & Sprouse in progress

Target state: Children's developing representations

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).

Transitive, single object	"Jack ___ it."	Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*
Transitive, double object	"Jack ___ Lily the thing."	Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Psych, subject experiencer	"Jack ___ it." *Experiencer SubjectMatter*	Control-subject	"Jack ___ to win." *Agent-like₁ Agent-like₂*
Psych, object experiencer	"It ___ Jack." *Causer Experiencer*	Raising-subject	"Jack ___ to win." *Agent-like*
Unergative	"Jack ___." *Agent-like*	*that*-complement	"Jack ___ that we won."
Unaccusative	"Jack ___." *Patient-like*	*whether*-complement	"Jack ___ whether we won."
Passivizable	"It was ___-en." *Patient-like*		





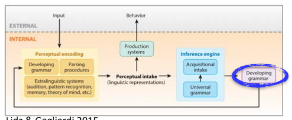
Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Children's developing representations

Give these developmental data, we may be particularly interested in these useful verb classes.

Transitive, single object	"Jack ___ it."
Transitive, double object	"Jack ___ Lily the thing."
Psych, subject experiencer	"Jack ___ it." *Experiencer SubjectMatter*
Psych, object experiencer	"It ___ Jack." *Causer Experiencer*
Unergative	"Jack ___." *Agent-like*
Unaccusative	"Jack ___." *Patient-like*
Passivizable	"It was ___-en." *Patient-like*
Raising-to-object (ECM)	"Jack ___ her to win." *Agent-like*
Control-object	"Jack ___ her to win." *Agent-like Goal-like*
Control-subject	"Jack ___ to win." *Agent-like₁ Agent-like₂*
Raising-subject	"Jack ___ to win." *Agent-like*
that-complement	"Jack ___ that we won."
whether-complement	"Jack ___ whether we won."

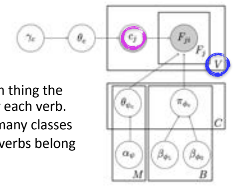


Lidz & Gagliardi 2015

Pearl & Sprouse in progress

Target state: Evaluating the results

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.

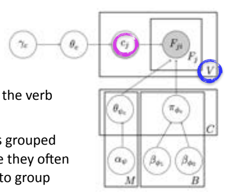


Each verb belongs to some class which determines its linguistic behavior.

FALL *unaccusatives*

Pearl & Sprouse in progress

Target state: Evaluating the results



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

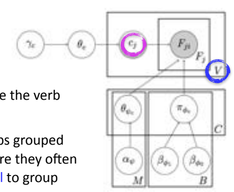
FALL *unaccusatives*

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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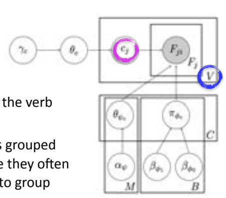
Implementation: Pairwise precision 0.0 <= PairPrec <= 1.0

$$\frac{\text{\# of pairs in inferred class that are the same kind}}{\text{total \# of pairs in inferred class}}$$

Pearl & Sprouse in progress

Target state: Evaluating the results



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Implementation: Pairwise precision 0.0 <= PairPrec <= 1.0

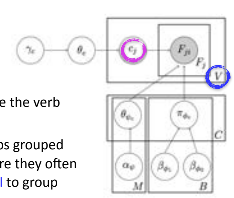
$$\frac{\text{\# of pairs in inferred class that are the same kind}}{\text{total \# of pairs in inferred class}}$$

Example: inferred class 6

FALL *COME* *HAPPEN* *WAKE* *CHIRP*

Pearl & Sprouse in progress

Target state: Evaluating the results



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

FALL *unaccusatives*

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Implementation: Pairwise precision 0.0 <= PairPrec <= 1.0

$$\frac{\text{\# of pairs in inferred class that are the same kind}}{\text{total \# of pairs in inferred class}}$$

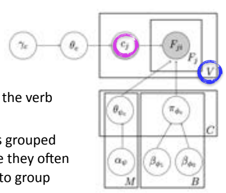
Example: inferred class 6

FALL *COME* *HAPPEN* *WAKE* *CHIRP*

Comparison class: unaccusatives

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: Pairwise precision 0.0 <= PairPrec <= 1.0

$$\frac{\text{\# of pairs in inferred class that are the same kind}}{\text{total \# of pairs in inferred class}}$$

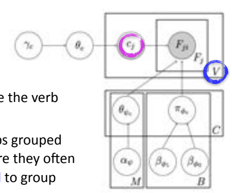
Example: inferred class 6

FALL +unacc, HAPPEN +unacc, COME +unacc, WAKE -unacc, CHIRP -unacc

Comparison class: unaccusatives

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?

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Implementation: Pairwise precision 0.0 <= PairPrec <= 1.0

$$\frac{\text{\# of pairs in inferred class that are the same kind}}{\text{total \# of pairs in inferred class}}$$

fall-happen, fall-come, fall-wake, fall-chirp, happen-come, happen-wake, happen-chirp, come-wake, come-chirp, wake-chirp

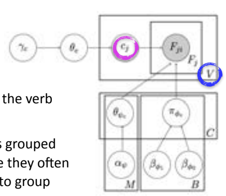
Example: inferred class 6

FALL +unacc, HAPPEN +unacc, COME +unacc, WAKE -unacc, CHIRP -unacc

Comparison class: unaccusatives

Pearl & Sprouse in progress

Target state: Evaluating the results



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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: Pairwise precision 0.0 <= PairPrec <= 1.0

$$\frac{\text{\# of pairs in inferred class that are the same kind}}{\text{total \# of pairs in inferred class} = 10}$$

fall-happen, fall-come, fall-wake, fall-chirp, happen-come, happen-wake, happen-chirp, come-wake, come-chirp, wake-chirp

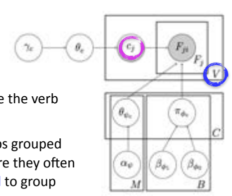
Example: inferred class 6

FALL +unacc, HAPPEN +unacc, COME +unacc, WAKE -unacc, CHIRP -unacc

Comparison class: unaccusatives

Pearl & Sprouse in progress

Target state: Evaluating the results



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FALL unaccusatives

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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: Pairwise precision 0.0 <= PairPrec <= 1.0

# of pairs in inferred class that are the same kind = 4

total # of pairs in inferred class = 10

fall-happen, fall-come, fall-wake, fall-chirp, happen-come, happen-wake, happen-chirp, come-wake, come-chirp, wake-chirp

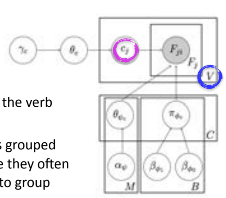
Example: inferred class 6

FALL +unacc, HAPPEN +unacc, COME +unacc, WAKE -unacc, CHIRP -unacc

Comparison class: unaccusatives

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.

Not very homogeneous for unaccusatives

Implementation: Pairwise precision = 0.40

# of pairs in inferred class that are the same kind = 4

total # of pairs in inferred class = 10

fall-happen, fall-come, fall-wake, fall-chirp, happen-come, happen-wake, happen-chirp, come-wake, come-chirp, wake-chirp

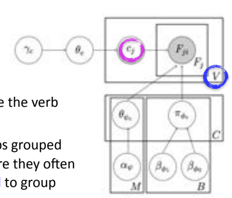
Example: inferred class 6

FALL +unacc, HAPPEN +unacc, COME +unacc, WAKE -unacc, CHIRP -unacc

Comparison class: unaccusatives

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: Pairwise precision

$$\frac{\text{\# of pairs in inferred class that are the same kind}}{\text{total \# of pairs in inferred class}}$$

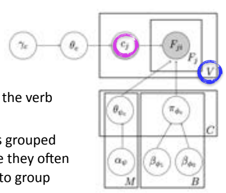
Example: inferred class 6

FALL -trans2, HAPPEN -trans2, COME -trans2, WAKE -trans2, CHIRP -trans2

Comparison class: transitive, double object

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: Pairwise precision

$\frac{\text{\# of pairs in inferred class that are the same kind}}{\text{total \# of pairs in inferred class}}$ = 10

fall-happen, fall-come, fall-wake, fall-chirp, happen-come, happen-wake, happen-chirp, come-wake, come-chirp, wake-chirp

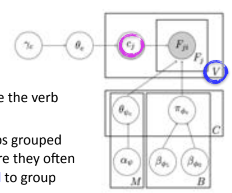
Example: inferred class 6

FALL -trans2, COME -trans2, HAPPEN -trans2, WAKE -trans2, CHIRP -trans2

Comparison class: transitive, double object

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.

very homogeneous for transitive verbs that take a double object

Implementation: Pairwise precision = 1.00

$\frac{\text{\# of pairs in inferred class that are the same kind} = 10}{\text{total \# of pairs in inferred class} = 10}$

fall-happen, fall-come, fall-wake, fall-chirp, happen-come, happen-wake, happen-chirp, come-wake, come-chirp, wake-chirp

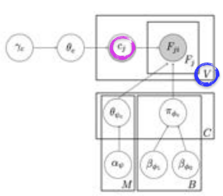
Example: inferred class 6

FALL -trans2, COME -trans2, HAPPEN -trans2, WAKE -trans2, CHIRP -trans2

Comparison class: transitive, double object

Pearl & Sprouse in progress

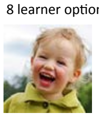
Target state: Evaluating the results



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

FALL | unaccusatives

8 learner options



-tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping)

+tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping)

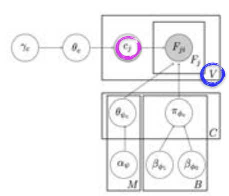
PairPrec

Inferred Classes

Average across all inferred classes.

Pearl & Sprouse in progress

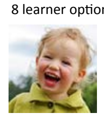
Target state: Evaluating the results



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

FALL | unaccusatives

8 learner options



-tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping)

+tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping)

PairPrec

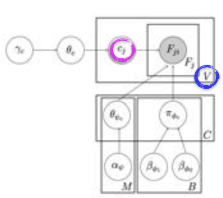
Inferred Classes

Random baseline

When we randomly assign the verbs to classes of the same size as the inferred classes. This is how much utility there is in deciding to make this many classes and make them of these sizes.

Pearl & Sprouse in progress

Target state: Evaluating the results



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

FALL | unaccusatives

8 learner options

-tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping)

+tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping)

PairPrec

Inferred Classes

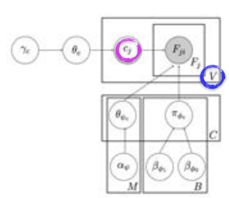
Random baseline

One Class Baseline

When we assign all the verbs to a single class. This shows how much separation there is, using this adult distinction. If very few verbs are separated out (ex: only 2 verbs are psych-object experiencer in our dataset out of 102), this baseline is near 1 for that distinction. Upshot: dividing into classes for that distinction isn't terribly useful to begin with.

Pearl & Sprouse in progress

Target state: Evaluating the results



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

FALL | unaccusatives

8 learner options

-tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping)

+tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping)

PairPrec

Inferred Classes

Score

Random baseline

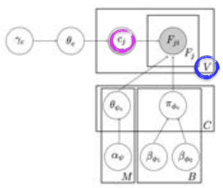
One Class Baseline

If the InferredClass pairwise precision is significantly higher than the random baseline, we know the classes inferred by this learner are more useful than just dividing verbs randomly into this many classes.

Upshot: There's something useful about these particular inferred classes.

Pearl & Sprouse in progress

Target state: Evaluating the results



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

FALL | unaccusatives

8 learner options

-tense/aspect | +tense/aspect

UTAH | rUTAH | UTAH | rUTAH

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

Inferred Classes — Score

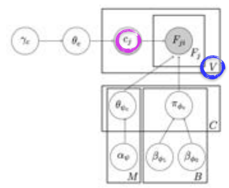
Random baseline

One Class Baseline

It's also informative to know how the Inferred Classes compare to the One Class baseline — if their precision is better, it's useful to divide the verbs into classes this way. Otherwise, it isn't.

Pearl & Sprouse in progress

Target state: Evaluating the results



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

FALL | unaccusatives

8 learner options

-tense/aspect | +tense/aspect

UTAH | rUTAH | UTAH | rUTAH

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

Inferred Classes — Score

Random baseline

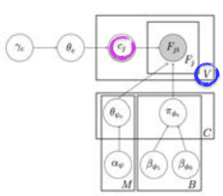
One Class Baseline

Conversely, if the InferredClass pairwise precision isn't significantly higher (or is even significantly lower) than the random baseline, we know the classes inferred by this learner aren't more useful than just dividing verbs randomly into this many classes.

Upshot: There isn't anything particularly useful about these inferred classes.

Pearl & Sprouse in progress

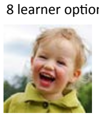
Target state: Evaluating the results



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

FALL | unaccusatives

8 learner options



-tense/aspect | +tense/aspect

UTAH | rUTAH | UTAH | rUTAH

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

Inferred Classes — Score

Random baseline

One Class Baseline

Similarly, it's also informative to know if the Inferred Classes precision isn't better (or is in fact worse) than the One Class baseline. In this case, it isn't useful to divide the verbs into classes this way.

Pearl & Sprouse in progress

Target state: Evaluating the results

For now, let's focus on the classes we know children distinguish.

by 2 years old

Transitive, single object — "Jack ___ it." (*Agent-like Patient-like*)

Unergative — "Jack ___." (*Agent-like*)

Unaccusative — "Jack ___." (*Patient-like*)

by 3 or 4 years old

Control-subject — "Jack ___ to win." (*Agent-like₁ Agent-like₂*)

Raising-subject — "Jack ___ to win." (*Agent-like*)

Passivizable — "It was ___-en." (*Patient-like*)

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

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

-tense/aspect | +tense/aspect

UTAH | rUTAH | UTAH | rUTAH

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

Inferred Classes

Random baseline

One Class Baseline

Pearl & Sprouse in progress

Target state: Evaluating the results

Transitives (with a single object) seem to be recognized as early as 28 months old in English: Yuan & Fisher 2009, Scott & Fisher 2009.

Transitive, single object — "Jack ___ it." (*Agent-like Patient-like*) — *80 of 102: drop, help, want …*

Transitives-1obj

-tense/aspect | +tense/aspect

UTAH | rUTAH | UTAH | rUTAH

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

Inferred Classes

Random baseline

One Class Baseline

Pearl & Sprouse in progress

Target state: Evaluating the results

Transitives (with a single object) seem to be recognized as early as 28 months old in English: Yuan & Fisher 2009, Scott & Fisher 2009.

Transitive, single object — "Jack ___ it." (*Agent-like Patient-like*) — *80 of 102: drop, help, want …*

Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes								
Random baseline								
One Class Baseline	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658

Pearl & Sprouse in progress

Target state: Evaluating the results

Transitives (with a single object) seem to be recognized as early as 28 months old in English: Yuan & Fisher 2009, Scott & Fisher 2009.

Transitive, single object — "Jack ___ it." (Agent-like Patient-like) — *80 of 102: drop, help, want …*

Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.818	0.757	0.783	0.750	0.659	0.658	0.663	0.650
Random baseline	0.654	0.653	0.667	0.661	0.659	0.660	0.640	0.656
One Class Baseline	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658

Pearl & Sprouse in progress

Target state: Evaluating the results

Transitives (with a single object) seem to be recognized as early as 28 months old in English: Yuan & Fisher 2009, Scott & Fisher 2009.

Transitive, single object — "Jack ___ it." (Agent-like Patient-like) — *80 of 102: drop, help, want …*

For identifying +/-transitive-single-object, the inferred classes for all learners who ignore tense/aspect information are better than the random baseline and better than just not bothering to make more than one class. However, this isn't true when the learners pay attention to tense/aspect information.

Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.818	0.757	0.783	0.750	0.659	0.658	0.663	0.650
Random baseline	0.654	0.653	0.667	0.661	0.659	0.660	0.640	0.656
One Class Baseline	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658

Pearl & Sprouse in progress

Target state: Evaluating the results

Transitives (with a single object) seem to be recognized as early as 28 months old in English: Yuan & Fisher 2009, Scott & Fisher 2009.

Transitive, single object — "Jack ___ it." (Agent-like Patient-like) — *80 of 102: drop, help, want …*

Upshot: Children shouldn't pay attention to tense/aspect information. This doesn't inform UTAH vs. rUTAH or +/-exp-mapping.

Also, the simple syntactic skeleton is sufficient for syntactic cue information.

Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.818	0.757	0.783	0.750	0.659	0.658	0.663	0.650
Random baseline	0.654	0.653	0.667	0.661	0.659	0.660	0.640	0.656
One Class Baseline	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658

Pearl & Sprouse in progress

Target state: Evaluating the results

Transitives (with a single object) seem to be recognized as early as 28 months old in English: Yuan & Fisher 2009, Scott & Fisher 2009.

Transitive, single object — "Jack ___ it." (Agent-like Patient-like) — *80 of 102: drop, help, want …*

Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.818	0.757	0.783	0.750	0.659	0.658	0.663	0.650
Random baseline	0.654	0.653	0.667	0.661	0.659	0.660	0.640	0.656
One Class Baseline	0.658	0.658	0.658	0.658	0.658	0.658	0.658	0.658

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unaccusative — "Jack ___." (Patient-like) — *15 of 102: break, drop, fall, …*

Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes								
Random baseline								
One Class Baseline								

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unaccusative — "Jack ___." (Patient-like) — *15 of 102: break, drop, fall, …*

Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes								
Random baseline								
One Class Baseline	0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unaccusative "Jack ___." Patient-like *15 of 102: break, drop, fall, …*

Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes	0.806	0.785	0.805	0.792	0.819	0.836	0.824	0.816
Random baseline	0.743	0.758	0.745	0.747	0.746	0.747	0.750	0.748
One Class Baseline	0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unaccusative "Jack ___." Patient-like *15 of 102: break, drop, fall, …*

For identifying +/-unaccusative, the inferred classes for all learners but one are better than the random baseline, and all are better than just not bothering to make more than one class.

Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes	0.806	0.785	0.805	0.792	0.819	0.836	0.824	0.816
Random baseline	0.743	0.758	0.745	0.747	0.746	0.747	0.750	0.748
One Class Baseline	0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unaccusative "Jack ___." Patient-like *15 of 102: break, drop, fall, …*

Upshot: Either UTAH or rUTAH will work. But if children are using the UTAH classification of thematic roles, they need to either expect the mapping to hold absolutely or heed tense/aspect information. Given this, the simple syntactic skeleton is sufficient for syntactic cue information.

Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes	0.806	0.785	0.805	0.792	0.819	0.836	0.824	0.816
Random baseline	0.743	0.758	0.745	0.747	0.746	0.747	0.750	0.748
One Class Baseline	0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unaccusative "Jack ___." Patient-like *15 of 102: break, drop, fall, …*

Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes	0.806	0.785	0.805	0.792	0.819	0.836	0.824	0.816
Random baseline	0.743	0.758	0.745	0.747	0.746	0.747	0.750	0.748
One Class Baseline	0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unergative "Jack ___." Agent-like *21 of 102: climb, jump, sleep …*

Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes								
Random baseline								
One Class Baseline								

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unergative "Jack ___." Agent-like *21 of 102: climb, jump, sleep …*

Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes								
Random baseline								
One Class Baseline	0.670	0.670	0.670	0.670	0.670	0.670	0.670	0.670

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unergative "Jack ___." *Agent-like* *21 of 102: climb, jump, sleep …*

Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.843	0.894	0.872	0.844	0.829	0.841	0.812	0.843
Random baseline	0.663	0.681	0.684	0.671	0.677	0.675	0.670	0.687
One Class Baseline	0.670	0.670	0.670	0.670	0.670	0.670	0.670	0.670

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unergative "Jack ___." *Agent-like* *21 of 102: climb, jump, sleep …*

For identifying +/-unergative, the inferred classes for all learners are better than the random baseline, and all are better than just not bothering to make more than one class.

Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.843	0.894	0.872	0.844	0.829	0.841	0.812	0.843
Random baseline	0.663	0.681	0.684	0.671	0.677	0.675	0.670	0.687
One Class Baseline	0.670	0.670	0.670	0.670	0.670	0.670	0.670	0.670

Pearl & Sprouse in progress

Target state: Evaluating the results

Unaccusatives seem to be distinguished early from unergatives: Hebrew (Friedmann 2007), Italian (Snyder et al. 1995), English (Pierce 1989, Pierce 1992, Deprez 1993, Deprez 1994): children under 2 years old.

Unergative "Jack ___." *Agent-like* *21 of 102: climb, jump, sleep …*

Upshot: Unergatives are easy with any of this prior knowledge, which includes using the simple syntactic skeleton for syntactic cue information.

Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.843	0.894	0.872	0.844	0.829	0.841	0.812	0.843
Random baseline	0.663	0.681	0.684	0.671	0.677	0.675	0.670	0.687
One Class Baseline	0.670	0.670	0.670	0.670	0.670	0.670	0.670	0.670

Pearl & Sprouse in progress

Target state: Evaluating the results

Unergatives
Unaccusatives
Transitives-1obj

-tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping); +tense/aspect: UTAH (+exp-mapping, -exp-mapping), rUTAH (+exp-mapping, -exp-mapping)

PairPrec

Big picture break: For verb distinctions learned by around age two…

(i) It's useful to ignore tense and aspect information (Transitive-1obj). Open question: Do we think young children do this?

(ii) Learning unaccusatives and unergatives will generally work well using this information, in almost any combination.
(except [UTAH and -exp-mapping and -tense/aspect])

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Raising-subject "Jack ___ to win." *Agent-like* *8 of 102: happen, keep, need…*

Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes								
Random baseline								
One Class Baseline								

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Raising-subject "Jack ___ to win." *Agent-like* *8 of 102: happen, keep, need…*

Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes								
Random baseline								
One Class Baseline	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Raising-subject "Jack ___ to win." Agent-like *8 of 102: happen, keep, need...*

Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.886	0.861	0.859	0.879	0.836	0.837	0.834	0.825
Random baseline	0.866	0.853	0.857	0.863	0.865	0.853	0.862	0.855
One Class Baseline	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Raising-subject "Jack ___ to win." Agent-like *8 of 102: happen, keep, need...*

For identifying +/-raising-subject, only one learner does better than the random baseline, and several do worse. (Some do better than not bothering to make multiple classes at all... but often not by much.) This is a much more selective result.

Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.886	0.861	0.859	0.879	0.836	0.837	0.834	0.825
Random baseline	0.866	0.853	0.857	0.863	0.865	0.853	0.862	0.855
One Class Baseline	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Raising-subject "Jack ___ to win." Agent-like *8 of 102: happen, keep, need...*

Upshot: Only UTAH will work, and only if children expect the mapping to hold absolutely and ignore tense/aspect information. In this case only, the simple syntactic skeleton is (barely?) sufficient for syntactic cue information.

Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.886	0.861	0.859	0.879	0.836	0.837	0.834	0.825
Random baseline	0.866	0.853	0.857	0.863	0.865	0.853	0.862	0.855
One Class Baseline	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Raising-subject "Jack ___ to win." Agent-like *8 of 102: happen, keep, need...*

Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes	0.886	0.861	0.859	0.879	0.836	0.837	0.834	0.825
Random baseline	0.866	0.853	0.857	0.863	0.865	0.853	0.862	0.855
One Class Baseline	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Control-subject "Jack ___ to win." Agent-like$_1$ Agent-like$_2$ *11 of 102: forget, try, want...*

Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes								
Random baseline								
One Class Baseline								

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Control-subject "Jack ___ to win." Agent-like$_1$ Agent-like$_2$ *11 of 102: forget, try, want...*

Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	-tense/aspect UTAH -exp-mapping	-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
Inferred Classes								
Random baseline								
One Class Baseline	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Control-subject "Jack ___ to win." Agent-like$_1$ Agent-like$_2$ *11 of 102: forget, try, want…*

Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping
Inferred Classes	0.749	0.684	0.715	0.703	0.633	0.633	0.614	0.660
Random baseline	0.806	0.805	0.857	0.820	0.804	0.804	0.807	0.808
One Class Baseline	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Control-subject "Jack ___ to win." Agent-like$_1$ Agent-like$_2$ *11 of 102: forget, try, want…*

For identifying +/-control-subject, no learners are better than the random baseline or even better than not bothering to make multiple classes at all (though using UTAH, ignoring tense/aspect info, and expecting the mapping to hold absolutely does relatively better than the rest). These learning assumptions are insufficient to separate out the control-subject verbs.

Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping
Inferred Classes	0.749	0.684	0.715	0.703	0.633	0.633	0.614	0.660
Random baseline	0.806	0.805	0.857	0.820	0.804	0.804	0.807	0.808
One Class Baseline	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Control-subject "Jack ___ to win." Agent-like$_1$ Agent-like$_2$ *11 of 102: forget, try, want…*

Upshot: No learners work. Possible problem (besides data sparseness): The simple syntactic skeleton isn't sufficient for syntactic cue information. Children need a more sophisticated representation of syntactic structure.

Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping
Inferred Classes	0.749	0.684	0.715	0.703	0.633	0.633	0.614	0.660
Random baseline	0.806	0.805	0.857	0.820	0.804	0.804	0.807	0.808
One Class Baseline	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Control-subject "Jack ___ to win." Agent-like$_1$ Agent-like$_2$ *11 of 102: forget, try, want…*

Possible connection to developmental data: it's enough to recognize "raising-subject verbs" and "NOT-raising-subject-verbs" (which happen to be control-subject verbs in the experimental setups). In particular, the learning cue is specific to raising-subject verbs (i.e., they have inanimate subjects).

Open question: How would these learners perform in those experimental setups?

Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping
Inferred Classes	0.749	0.684	0.715	0.703	0.633	0.633	0.614	0.660
Random baseline	0.806	0.805	0.857	0.820	0.804	0.804	0.807	0.808
One Class Baseline	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806

Pearl & Sprouse in progress

Target state: Evaluating the results

By 3 to 4 years old, English children have figured out that inanimate subjects can distinguish between raising-subject and control-subject verbs (Becker 2014). In particular, raising-subject verbs allow inanimate subjects. So, they've likely figured out these classes.

Control-subject "Jack ___ to win." Agent-like$_1$ Agent-like$_2$ *11 of 102: forget, try, want…*

Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping
Inferred Classes	0.749	0.684	0.715	0.703	0.633	0.633	0.614	0.660
Random baseline	0.806	0.805	0.857	0.820	0.804	0.804	0.807	0.808
One Class Baseline	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806

Pearl & Sprouse in progress

Target state: Evaluating the results

Passives seem to be used appropriately by 4 years old (with the correct structural features available by 3 years old): Crain, Thornton & Murasugi, 1987, Budwig 1990, Tomasello, Brooks, & Stern 1998, Huttenlocher et al. 2004.

Passivizable "It was ___-en." Patient-like *79 of 102: buy, like, turn…*

Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping
Inferred Classes								
Random baseline								
One Class Baseline								

Pearl & Sprouse in progress

Target state: Evaluating the results

Passives seem to be used appropriately by 4 years old (with the correct structural features available by 3 years old): Crain, Thornton & Murasugi, 1987, Budwig 1990, Tomasello, Brooks, & Stern 1998, Huttenlocher et al. 2004.

Passivizable "It was ___-en." (Patient-like) *79 of 102: buy, like, turn…*

Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping	+tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping
Inferred Classes								
Random baseline								
One Class Baseline	0.647	0.647	0.647	0.647	0.647	0.647	0.647	0.647

Pearl & Sprouse in progress

Target state: Evaluating the results

Passives seem to be used appropriately by 4 years old (with the correct structural features available by 3 years old): Crain, Thornton & Murasugi, 1987, Budwig 1990, Tomasello, Brooks, & Stern 1998, Huttenlocher et al. 2004.

Passivizable "It was ___-en." (Patient-like) *79 of 102: buy, like, turn…*

Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping	+tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping
Inferred Classes	0.810	0.751	0.775	0.741	0.610	0.615	0.624	0.606
Random baseline	0.653	0.643	0.654	0.642	0.665	0.649	0.642	0.642
One Class Baseline	0.647	0.647	0.647	0.647	0.647	0.647	0.647	0.647

Pearl & Sprouse in progress

Target state: Evaluating the results

Passives seem to be used appropriately by 4 years old (with the correct structural features available by 3 years old): Crain, Thornton & Murasugi, 1987, Budwig 1990, Tomasello, Brooks, & Stern 1998, Huttenlocher et al. 2004.

Passivizable "It was ___-en." (Patient-like) *79 of 102: buy, like, turn…*

For identifying +/-passivizable, the inferred classes for all learners who ignore tense/aspect information are better than the random baseline and better than just not bothering to make more than one class. However, this isn't true when the learners pay attention to tense/aspect information. (Similar to Transitive-1obj)

Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping	+tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping
Inferred Classes	0.810	0.751	0.775	0.741	0.610	0.615	0.624	0.606
Random baseline	0.653	0.643	0.654	0.642	0.665	0.649	0.642	0.642
One Class Baseline	0.647	0.647	0.647	0.647	0.647	0.647	0.647	0.647

Pearl & Sprouse in progress

Target state: Evaluating the results

Passives seem to be used appropriately by 4 years old (with the correct structural features available by 3 years old): Crain, Thornton & Murasugi, 1987, Budwig 1990, Tomasello, Brooks, & Stern 1998, Huttenlocher et al. 2004.

Passivizable "It was ___-en." (Patient-like) *79 of 102: buy, like, turn…*

Upshot: Children shouldn't pay attention to tense/aspect information (though perhaps this is a data sparseness problem right now - in general, it seems like that would be very helpful information for identifying passives). This class doesn't inform UTAH vs. rUTAH or +/-exp-mapping.

Also, the simple syntactic skeleton is sufficient for syntactic cue information.

Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping	+tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping
Inferred Classes	0.810	0.751	0.775	0.741	0.610	0.615	0.624	0.606
Random baseline	0.653	0.643	0.654	0.642	0.665	0.649	0.642	0.642
One Class Baseline	0.647	0.647	0.647	0.647	0.647	0.647	0.647	0.647

Pearl & Sprouse in progress

Target state: Evaluating the results

Passives seem to be used appropriately by 4 years old (with the correct structural features available by 3 years old): Crain, Thornton & Murasugi, 1987, Budwig 1990, Tomasello, Brooks, & Stern 1998, Huttenlocher et al. 2004.

Passivizable "It was ___-en." (Patient-like) *79 of 102: buy, like, turn…*

Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping	+tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping
Inferred Classes	0.810	0.751	0.775	0.741	0.610	0.615	0.624	0.606
Random baseline	0.653	0.643	0.654	0.642	0.665	0.649	0.642	0.642
One Class Baseline	0.647	0.647	0.647	0.647	0.647	0.647	0.647	0.647

Pearl & Sprouse in progress

Target state: Evaluating the results

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, subject-experiencer "Jack ___ it." (Experiencer, SubjectMatter) *0 of 102*

Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

PairPrec	-tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping	+tense/aspect UTAH +exp-mapping	UTAH -exp-mapping	rUTAH +exp-mapping	rUTAH -exp-mapping
Inferred Classes								
Random baseline								
One Class Baseline								

Pearl & Sprouse in progress

Target state: Evaluating the results

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, subject-experiencer "Jack ___ it." *Experiencer* *SubjectMatter* ***0 of 102***

Data sparseness limitation: no subject-experiencer psych verbs in dataset appearing frequently enough (10 or more times). So we can't tell from this dataset.

Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes								
Random baseline								
One Class Baseline								

Pearl & Sprouse in progress

Target state: Evaluating the results

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* *2 of 102: hurt, move*

Psych-obj-exper
Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes								
Random baseline								
One Class Baseline								

Pearl & Sprouse in progress

Target state: Evaluating the results

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* *2 of 102: hurt, move*

Psych-obj-exper
Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes								
Random baseline								
One Class Baseline	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961

Pearl & Sprouse in progress

Target state: Evaluating the results

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* *2 of 102: hurt, move*

Psych-obj-exper
Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes	0.967	0.986	0.976	0.976	0.989	0.990	0.991	0.992
Random baseline	0.959	0.968	0.968	0.965	0.953	0.960	0.962	0.968
One Class Baseline	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961

Pearl & Sprouse in progress

Target state: Evaluating the results

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* *2 of 102: hurt, move*

Because there are so few of these verbs in the dataset, there's not much to be gained by grouping verbs into more than one class. Still…for identifying +/-psych-obj-experiencer, the inferred classes for all learners but one are better than the random baseline, and all are better than just not bothering to make more than one class (if barely).

Psych-obj-exper
Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
PairPrec	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*	*+exp-mapping*	*-exp-mapping*
Inferred Classes	0.967	0.986	0.976	0.976	0.989	0.990	0.991	0.992
Random baseline	0.959	0.968	0.968	0.965	0.953	0.960	0.962	0.968
One Class Baseline	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961

Pearl & Sprouse in progress

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Upshot: Either UTAH or rUTAH will work. But if children are using the rUTAH classification of thematic roles, they need to either not expect the mapping to hold absolutely or heed tense/aspect information. Given this, the simple syntactic skeleton is sufficient for syntactic cue information.

Psych-obj-exper
Passivizable
Control-subject
Raising-subject
Unergatives
Unaccusatives
Transitives-1obj

	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
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Pearl & Sprouse in progress

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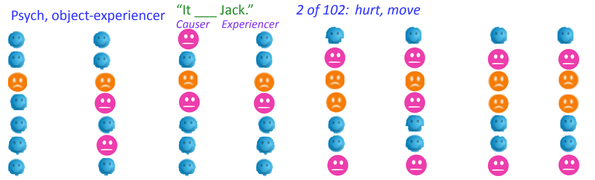

PairPrec	-tense/aspect				+tense/aspect			
	UTAH		rUTAH		UTAH		rUTAH	
	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping	+exp-mapping	-exp-mapping
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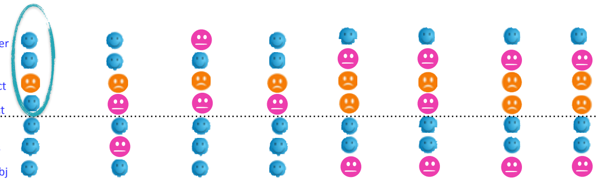
Pearl & Sprouse in progress

Target state: Evaluating the results



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

Big picture break: For verb distinctions learned around 3 or 4…

(i) It's typically useful to ignore tense and aspect information (except for Psych-obj-exper in one case).
Open question: Do we think older children do this?

(ii) The most promising combination across different verb classes seems to be UTAH, +exp-mapping, -tense/aspect (though still some issues with control-subject verbs).

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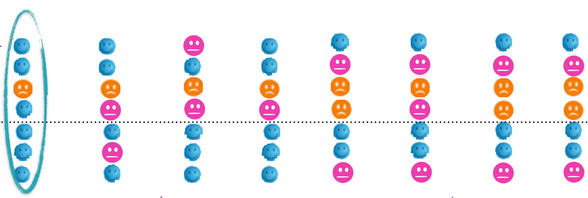
Target state: Evaluating the results



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

Big picture break: Over all verb classes…same story.

(i) It's typically useful to ignore tense and aspect information (Transitives-1obj, Psych-obj-exper).
Open question: When do we think children do this?

(ii) The most promising combination across different verb classes seems to be UTAH, +exp-mapping, -tense/aspect (though still some issues with control-subject verbs).

Pearl & Sprouse in progress

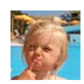
Learning strategy options

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.

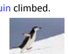
thematic-roles (likely derived from lower level conceptual info) = Agent, Experiencer, Patient, Theme, Goal, Source, Instrument…

Pearl & Sprouse in progress

UG proposal refinement

The Linking Problem: Pearl & Sprouse in progress

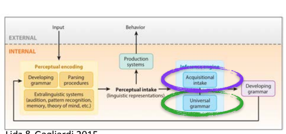
done-to
The ice melted.
The penguin climbed.
doer



Refining ideas about what implementations of Universal Grammar are consistently useful for acquisition (Ambridge et al. 2014, Pearl 2014): UTAH, expect the mapping to syntax a priori

Refining ideas about what needs to be true about the acquisitional intake for this implementation to be useful: abstract away from surface tense/aspect information

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



Lidz & Gagliardi 2015

What next?

Near future:

Test these learners on a larger data set to combat potential data sparseness issues. (In progress: annotating Valian corpus, which has ~25,000 utterances. Current studies with Brown-Eve corpus, which has ~14,000 utterances.)

Pearl & Sprouse in progress

What next?

Near future:
Other ways to evaluate the output of the modeled learners.

(1) Additional quantitative analysis: Other clustering metrics for assessing quality of inferred verb classes (ARI, VM, etc.)

(2) 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?

(3) Comparison with behavioral data: Does a learner, using the verb classes it's inferred, perform the same way children do in experimental setups?

(4) 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

What next?

Further future:
(1) 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?

(2) More sophisticated syntactic cues: What kind of structure is necessary for children to know in order to capture some of the trickier distinctions?

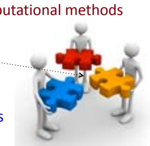
(3) More realistic assumptions about children:
- What if children only have some thematic roles available initially (and some syntactic structure), which they later build on? Do these theories still work/not work? For example, children might not begin by expecting a mapping to syntax to be there (< 2 years old: +/-exp-mapping didn't matter), but then derive it from experience and then expect the mapping by 3 to 4 years old (3-4 years old: +exp-mapping does better).
- What happens when we embed these theories in a learning model that learns incrementally and has cognitive constraints?

Pearl & Sprouse in progress

Big picture:
Understanding how children make linguistic generalizations

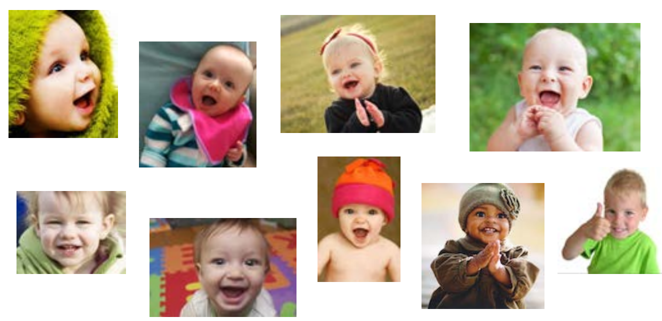
Precisely defining the components of any learning problem is necessary for making progress on how children solve that learning problem, which requires insights from many different methods.

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



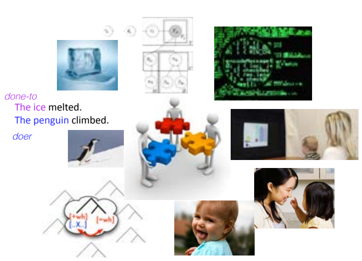
Biggest picture:
Computational acquisition modeling

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



Thank you!

Jon Sprouse



Computation of Language Laboratory
UC Irvine

This work was supported in part by NSF grant BCS-1347028.

Thematic roles & how to use them

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

The (relativized) Uniformity of Theta Assignment Hypothesis | UG knowledge

UTAH: Baker 1988, Baker 1997, Dowty 1991, Fillmore 1968, Grimshaw 1990, Jackendoff 1987, Perlmutter & Postal 1984, Speas 1990
Each thematic role maps to a specific syntactic position (grammatical role).

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)

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

("internal cause" = Rappaport-Hovav 1995)

She fears spiders.
Experiencer

Spiders frighten her.
Experiencer

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Patient-like = grammatical object

Patient
Theme
Experiencer
Subject Matter

("external cause")

control

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Theme
Experiencer *(*Baker: only when not subject)*
Subject Matter

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Experiencer

Spiders frighten her.
Experiencer

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

Location
Source
Goal
Benefactor
Instrument

control

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

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

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

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

raising

Pearl & Sprouse in progress

Thematic roles & how to use them

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

Mapping to Syntax

UG knowledge

The **U**niformity of **T**heta **A**ssignment **H**ypothesis:
Baker 1988, Baker 1997, Dowty 1991, Fillmore 1968, Grimshaw 1990, Jackendoff 1987, Perlmutter & Postal 1984, Speas 1990

UTAH

Intermediate representations

Thematic roles map to one of three categories.

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

Thematic roles & how to use them

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

rUTAH: Larson 1988, Larson 1990
Thematic roles are ordered relative to each other, with the highest thematic role mapping to the highest grammatical role (subject > object > indirect object).

control

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

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

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

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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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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)

control

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

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*

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doer *done-to*

raising

Pearl & Sprouse in progress

Thematic roles & how to use them

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

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.

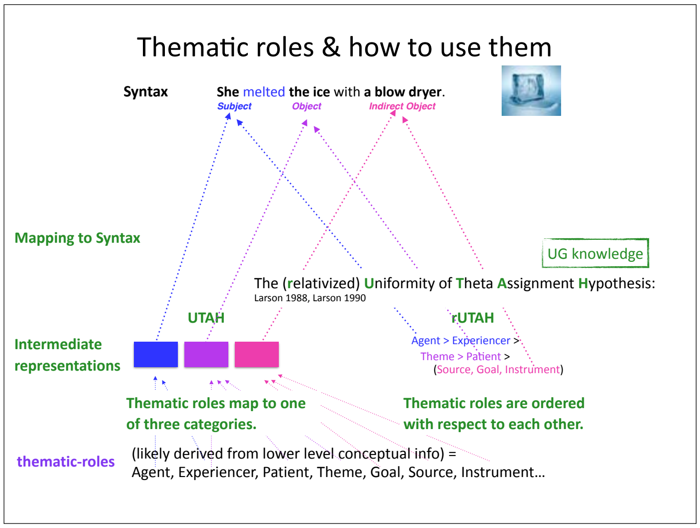
She fears spiders.
Experiencer ***Subject Matter***

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

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

Causer **>** ***Experiencer***
Subject ***Object***

Pearl & Sprouse in progress



Thematic roles & how to use them
Syntax
She melted the ice with a blow dryer.
Subject
Object
Indirect Object
Mapping to Syntax
UG knowledge
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Larson 1988, Larson 1990
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Intermediate representations
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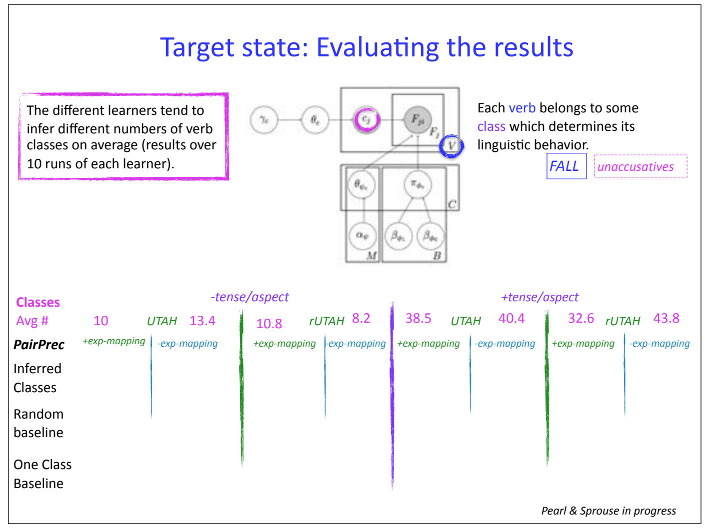
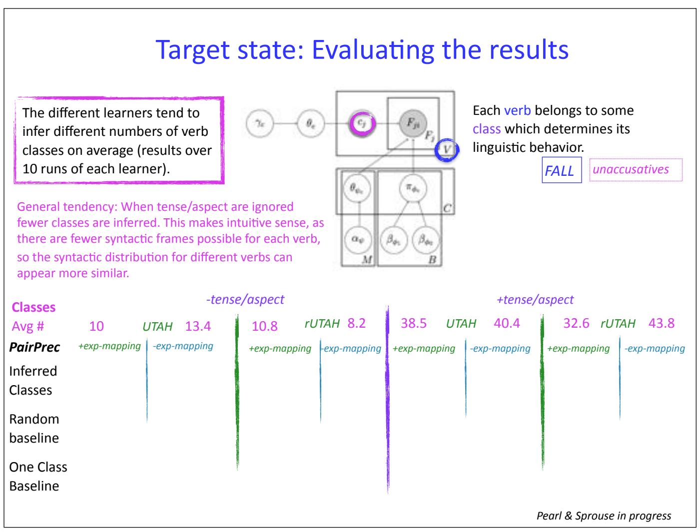


Target state: Evaluating the results
The different learners tend to infer different numbers of verb classes on average (results over 10 runs of each learner).
Each verb belongs to some class which determines its linguistic behavior.
FALL
unaccusatives
Classes
-tense/aspect
+tense/aspect
Avg #
10
UTAH
13.4
10.8
rUTAH
8.2
38.5
UTAH
40.4
32.6
rUTAH
43.8
PairPrec
+exp-mapping
-exp-mapping
Inferred Classes
Random baseline
One Class Baseline
Pearl & Sprouse in progress



Target state: Evaluating the results
The different learners tend to infer different numbers of verb classes on average (results over 10 runs of each learner).
Each verb belongs to some class which determines its linguistic behavior.
FALL
unaccusatives
General tendency: When tense/aspect are ignored fewer classes are inferred. This makes intuitive sense, as there are fewer syntactic frames possible for each verb, so the syntactic distribution for different verbs can appear more similar.
Classes
-tense/aspect
+tense/aspect
Avg #
10
UTAH
13.4
10.8
rUTAH
8.2
38.5
UTAH
40.4
32.6
rUTAH
43.8
PairPrec
+exp-mapping
-exp-mapping
Inferred Classes
Random baseline
One Class Baseline
Pearl & Sprouse in progress