Algorithms for learning the raising/control distinction from semantic information

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Table of Contents

A Type of Structural Ambiguity

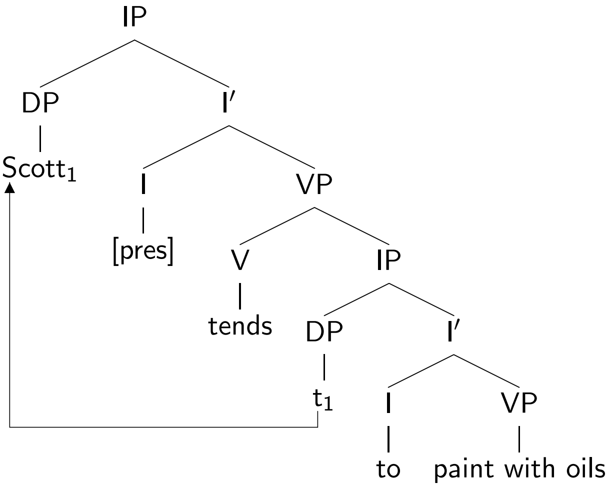
(1) Scott ______ to paint with oils.

a. Raising: Scott tends to paint with oils.

b. Control: Scott likes to paint with oils.

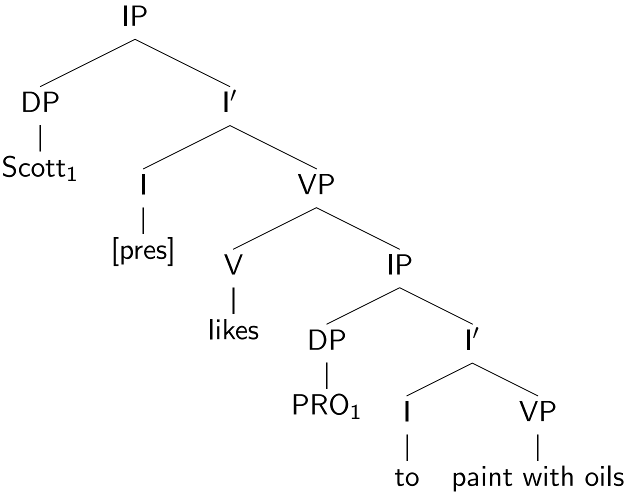
Raising

Scott tends to paint with oils.



Control

Scott likes to paint with oils.

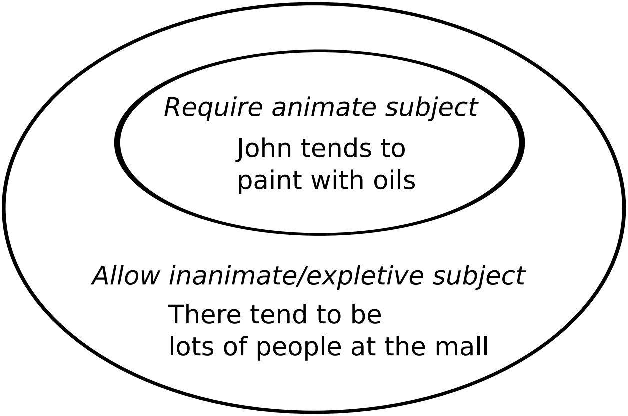


Raising & control comparison

- Raising verbs
  - No semantic relationship to subject
  - Raise subject of lower verb for syntactic subject
  - or use expletive subject (*it*, *there*)
- Control verbs
  - Semantic relationship to subject
  - Subject usually animate
  - Cannot occur with expletive subjects

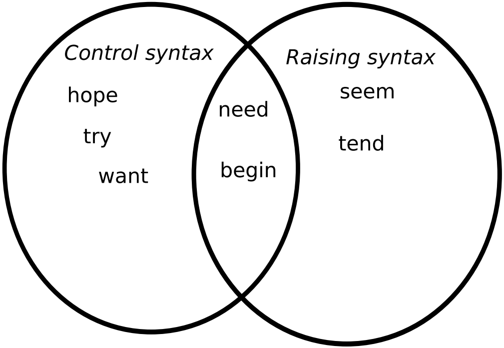
(2) a. It seems to be raining.
b. * It tried to be raining.
c. There tend to be arguments at poker games.
d. * There want to be arguments at poker games.

The subset principle



Assume a more restrictive grammar until you receive positive evidence that forces you to expand it.

The problem with subset-based learning



(3) a. It began to rain. (Raising)
b. Rodney began to beat up Zoe. (Control)

Child grammaticality test

Type	Item	3-year-olds		4-year-olds		5-year-olds	
		OK	silly	OK	silly	OK	silly
control/ compat.	The flower wants to be pink						**
control/ incompat	The flower wants to fly away		*		**		**
raising/ compat.	The hay seems to be on the ground		*		**		*
raising/ incompat	The hay seems to be excited		*		**		**

$*p \leq 0.05$, $**p \leq 0.01$

M. Becker, *There began to be a learnability puzzle*

Potential Semantic Cues from Input

$NP_{subject}$ ______ to Predicate

animate subject, eventive predicate → control verb

inanimate subject, stative predicate → raising verb

Results from adult experiment

Table: Responses by Subject Animacy and Predicate Eventivity

Sentence Type	Control	Raising	Ambig.	Other
Animate+Eventive	65%	5%	15%	15%
(*The driver . . . to hit the car*)				
Animate+Stative	40%	32.5%	20%	7.5%
(*These students . . . to belong*)				
Inanimate+Eventive	32.5%	17.5%	25%	25%
(*The boulder. . . to hit the car*)				
Inanimate+Stative	2.5%	70%	22.5%	5%
(*These shapes . . . to belong*)				

from Becker (2005)

CHILDES data

Verb	A+E	A+S	I+E	I+S
try	86	0	0	0
want	354	53	2	0
need	34	4	0	4
seem	0	4	4	5
gonna	1065	132	31	27

Switchboard data

Verb	A+E	A+S	I+E	I+S
try	149	12	1	0
want	342	123	3	0
need	208	62	3	23
seem	24	57	23	71
gonna	44	11	3	6
tend	36	37	10	9

Goals

- Graded classification of verbs
- Psychologically reasonable
  - Start permissive, become restrictive
  - Parallel processing
  - Simple operations

Raw proportions

For comparison: Fraction of animate subject + eventive predicate

CHILDES		
try	C	1.000
want	C	0.866
gonna	R	0.849
need	A	0.810
seem	R	0.000

Switchboard		
try	C	0.920
want	C	0.731
need	A	0.703
gonna	R	0.688
tend	R	0.391
seem	R	0.137

Switchboard data

Verb	A+E	A+S	I+E	I+S
try	149	12	1	0
want	342	123	3	0
need	208	62	3	23
seem	24	57	23	71
gonna	44	11	3	6
gonna-st	48	11	3	6
tend	36	37	10	9

gonna-st: A sensitivity test, same as *gonna* but with 4 more A+E.

Raw proportions

For comparison: Fraction of animate subject + eventive predicate

CHILDES		
try	C	1.000
want	C	0.866
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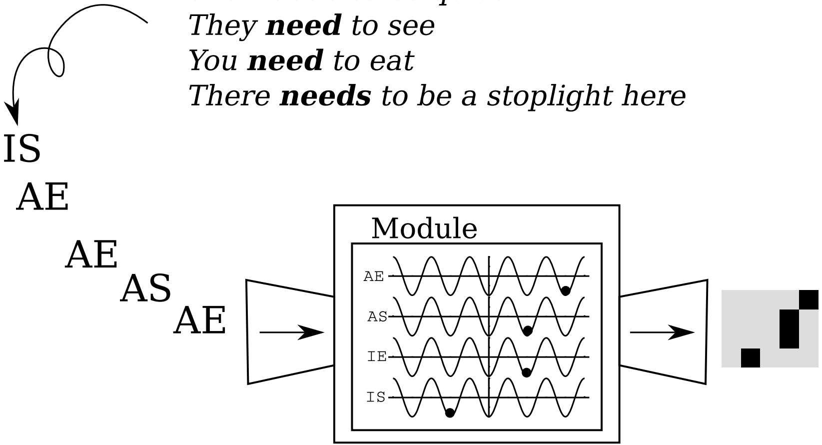
need	A	0.810
seem	R	0.000

Switchboard		
try	C	0.920
want	C	0.731
gonna-st	R	0.706
need	A	0.703
gonna	R	0.688
tend	R	0.391
seem	R	0.137

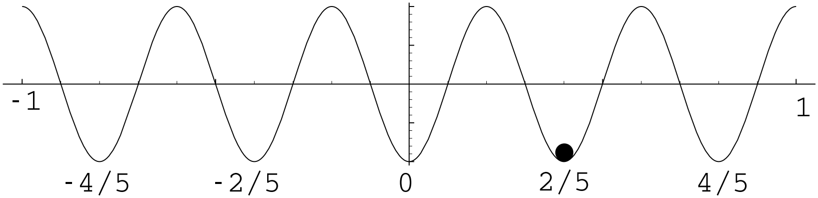
Particle-based learning module

*I **need** to leave*
*She **needs** to be quiet*
*They **need** to see*
*You **need** to eat*
*There **needs** to be a stoplight here*



Basic potential

- One particle for each of the four sentence types

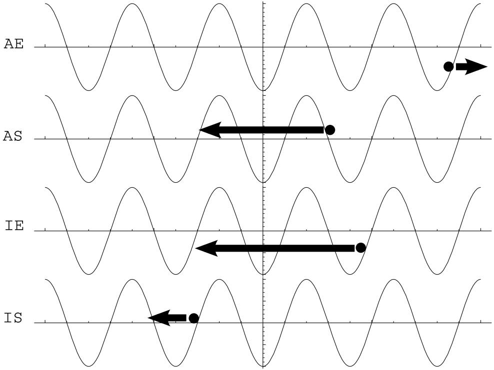


forbidden .... required

$$v = \cos 5\pi x$$

Force from a sentence

$$\mathbf{x}(t) = \begin{pmatrix} x_{\mathrm{AE}}(t) \\ x_{\mathrm{AS}}(t) \\ x_{\mathrm{IE}}(t) \\ x_{\mathrm{IS}}(t) \end{pmatrix}$$



Force from a sentence

If a sentence of type T arrives at time t_0, then it creates a force on the particles with potential

$$L(\mathbf{x}, t, T, t_0) = \begin{cases} 0 & \text{if } t < t_0, \\ \frac{1}{2} e^{-(t-t_0)/\sigma} \left\| \mathbf{x} - \mathbf{p}_T \right\|^2 & \text{if } t \geq t_0. \end{cases}$$

$$\mathbf{p}_{\mathrm{AE}} = \begin{pmatrix} 1 \\ -1/4 \\ -1/4 \\ -1/2 \end{pmatrix} \quad \mathbf{p}_{\mathrm{AS}} = \begin{pmatrix} -1/4 \\ 1 \\ -1/2 \\ -1/4 \end{pmatrix}$$

$$\mathbf{p}_{\mathrm{IE}} = \begin{pmatrix} -1/4 \\ -1/2 \\ 1 \\ -1/4 \end{pmatrix} \quad \mathbf{p}_{\mathrm{IS}} = \begin{pmatrix} -1/2 \\ -1/4 \\ -1/4 \\ 1 \end{pmatrix}$$

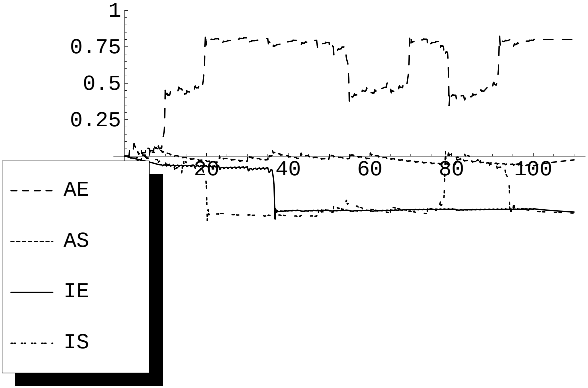
Complete potential

$$\frac{d^2\mathbf{x}(t)}{dt^2} = \mathbf{F}_{\text{field}} + \sum_{\text{inputs}} \mathbf{F}_{\text{input}} + \mathbf{F}_{\text{friction}}$$

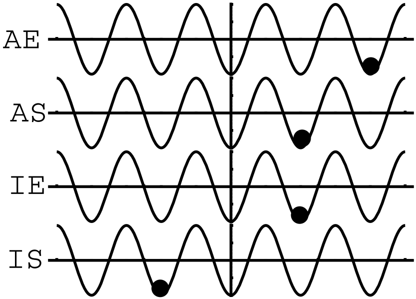
$$= -\operatorname{grad} V(\mathbf{x}(t)) - \gamma \left(\sum_i \operatorname{grad} L(\mathbf{x}(t), t, T_i, t_i) \right) - \beta \frac{d\mathbf{x}(t)}{dt}$$

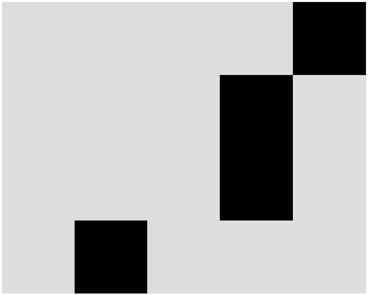
- $\gamma = 8$: relative magnitude of sentence force
- $\sigma = 10$: duration of sentence force
- $\beta = 8$: relative magnitude of drag force
- $t_i = i$: sentences arrive one every time unit

Sample run: learning *need* from CHILDES data

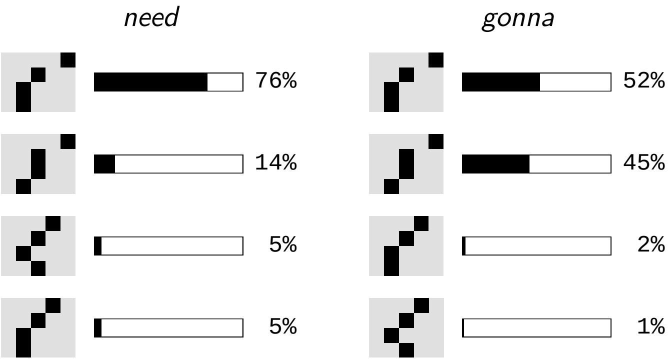


Results of many runs: Histogram key



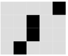
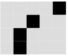


Results from 100 runs



Histograms of the learning algorithm using the sentence type proportions from CHILDES

Summary of most common patterns

	try		*want*		*need*		*gonna*	
	C	SB	C	SB	C	SB	C	SB
A 	100	47	5	0	14	0	45	23
B 	0	53	93	71	76	59	52	21
C 	0	0	1	16	5	27	2	21
other	0	0	1	13	5	14	1	35

Frequent patterns and the percentage of trial runs in which they occur. C means CHILDES, SB means Switchboard.

- *A* and *B* $\Longrightarrow$ Control tendency
- pattern variety $\Longrightarrow$ Raising tendency

Better index

Order by $A + B + \max(A, B, C)$

CHILDES		
try	C	200
want	C	191
$\Downarrow$ *raising*		*178.5*
need	A	166
$\Uparrow$ *control*		*157.5*
gonna	R	149
seem	R	0

Switchboard		
try	C	153
want	C	142
$\Downarrow$ *raising*		*130*
need	A	118
$\Uparrow$ *control*		*105*
gonna-st	R	92
gonna	R	67
tend	R	2
seem	R	0

Conclusion

- On-line learning
- Improved margins and robustness over A+E ratio
- Mimics child learning: permissive $\longrightarrow$ more restrictive
- Biologically reasonable

Implications

The learner assumes:

- isomorphic strings need not = isomorphic structures
- semantic relationships need not be local
- inanimate/expletive subjects are unlikely agents
    - $\rightarrow$ verbs that take inanimate/expletive subjects are unlikely to assign a subject θ-role

These assumptions should be made in general for verb learning (not just this case)

Expletive subjects

CHILDES

	there	it
gonna	1*	0
seem	0	6
others	0	0

Switchboard

	there	it
seem	8	?
used	4	?
gonna	1	?
tend	0	?
appear	0	?
need	16	?
others	0	?

*Sarah103: "I think there's gonna be a war tomorrow when it's time for us to leave"

A Continuum?

unambiguously raising	unambiguously control

tend, used-to, seem, need, begin, want, try, claim

Acknowledgements

We would like to thank Joan Bresnan and her lab for making the annotated Switchboard corpus available to M. Becker for this research.

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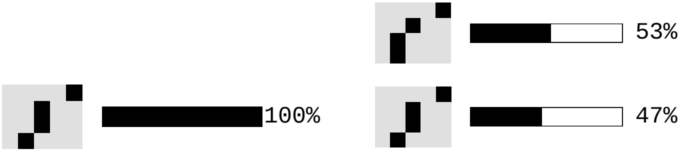
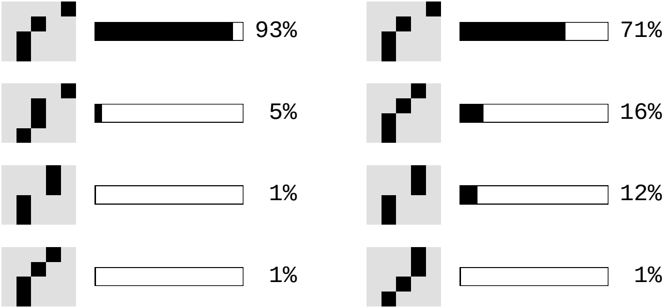
Results from many runs: Learning *try* (control)



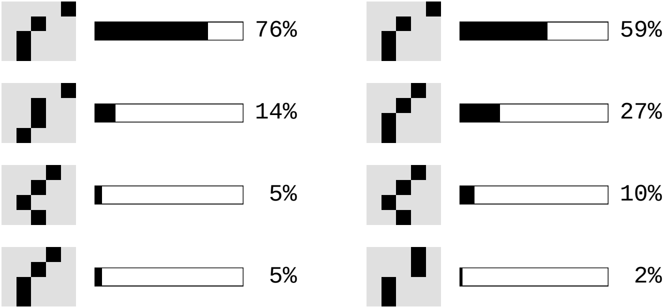
Histograms of the learning algorithm for *try* using the sentence type proportions from CHILDES (left) and Switchboard (right).

Results from many runs: Learning *want* (control)



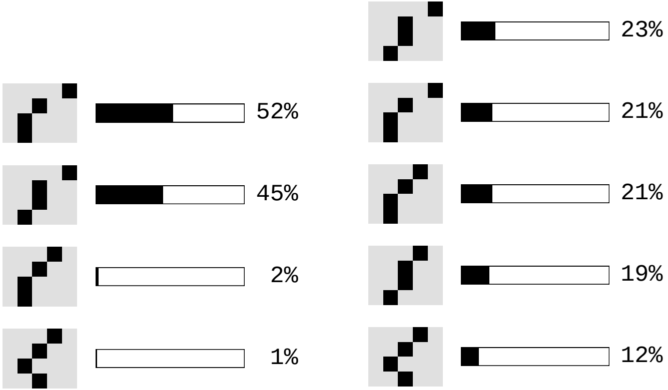
Histograms of the learning algorithm for *want* using the sentence type proportions from CHILDES (left) and Switchboard (right).

Results from many runs: Learning *need* (ambiguous)



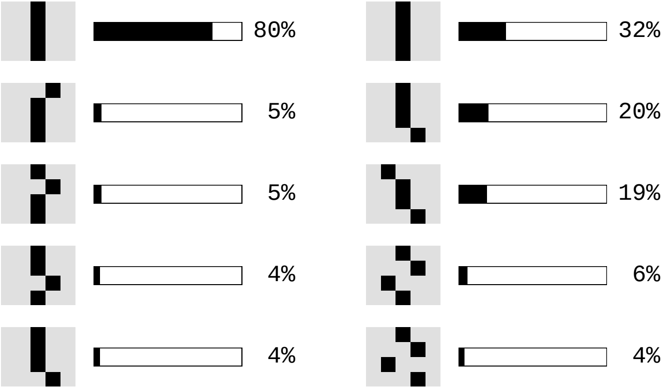
Histograms of the learning algorithm for *need* using the sentence type proportions from CHILDES (left) and Switchboard (right). Only the most common patterns are shown.

Results from many runs: Learning *gonna* (raising)



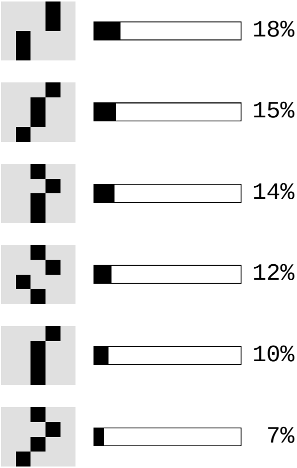
Histograms of the learning algorithm for *gonna* using the sentence type proportions from CHILDES (left) and Switchboard (right). Only the most common patterns are shown.

Results from many runs: Learning *seem* (raising)



Histograms of the learning algorithm for *seem* using equal sentence type proportions (left) and the sentence type proportions from Switchboard (right). Only the five most common patterns are shown.

Results from many runs: Learning *tend* (raising)



Histograms of the learning algorithm for *tend* using the sentence type proportions from Switchboard. Only the six most common